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APRIL 2017

WELCOME



Forty-five years. That's how much time has passed since a human walked on the Moon. It actually sounds a little preposterous when you say it out loud. Just think how much the world has changed in that time. We now have a permanent habitat in space. We can see almost any location on the planet from our sofas. And most of us carry computers that are far more sophisticated than the guidance computers used to send astronauts to the

Moon. Yet because of the cost, we've never gone back.

But it seems now there's a new surge of interest in returning to the Moon. PayPal and Tesla founder Elon Musk is offering a lunar flyby for space tourists next year, while NASA has suggested it could send its Orion spacecraft to the Moon as a dry run for Mars. So what will we actually gain by revisiting our neighbour? We put this question to an astronaut, a businessman, a philosopher, a biologist and a geologist to find out (p38).

This month, *Stargazing Live* returns! This time, Brian Cox and Dara O Briain will be ogling the jewels of the night sky live from Australia. But if you want to get a deeper understanding of how the cosmos works, then look no further. In this issue, Brian Cox and Jeff Forshaw kick off a new four-part series in which they elegantly unravel the fundamental fabric of our Universe (p64). Don't miss it.

Daniel Bennett

Daniel Bennett, Editor

IN THIS ISSUE



BRIAN COX

Physicist Brian is a familiar face on our TV screens. He joins Jeff Forshaw to demystify our Universe in the first part of our new series. → p64



JEFF FORSHAW

With a background in physics and has acted as consultant on several BBC shows. He's the ideal person to help us unravel the cosmos. → p64



KAT ARNEY

With a background in genetics and developmental biology, Kat is just the expert to investigate the world of genetic test kits. → p58

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Antisocial network

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58 Apps and services offering DNA-based advice on everything from planning a workout to choosing a wine are increasingly common. Kat Arney finds out more.

Jeff Forshaw and Brian Cox's guide to the cosmos

64 In Part 1 of our new series, Brian Cox and physicist Jeff Forshaw ponder the baffling idiosyncrasies of the space-time continuum.

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50



EYE OPENER

It takes two to tango

BUENOS AIRES,
ARGENTINA

Painted in the colours of the Argentine capital's two most famous football teams – River Plate in red and white, and Boca Juniors in yellow and blue – DevBot 1 and 2 race through the city's streets.

The driverless electric cars, developed by Roborace, need to communicate with each other and continually scan their environment to avoid collision. "It is so exciting to see these vehicles taking appropriate actions in order to guide themselves around the track," says Roborace CEO Denis Sverdlov.

Roborace hosts the first global championship for driverless cars, and this race on 18 February, watched by cheering crowds, was the first ever display of two autonomous cars on a race course at the same time. Unfortunately, an unexpected living competitor swerved DevBot 1 and 2 off their course: a dog caught up in the excitement broke through the barriers, which ended one car's race with a crash. Thankfully the cars' systems were advanced enough to avoid the canine intruder completely.

PHOTO: ROBORACE





EYE OPENER

Feeding frenzy


SHETLAND ISLES,
SCOTLAND

For gannets, dinner can quickly turn into a fierce battle. These duelling seabirds brave the turbulent waters of the North Sea to dive for mackerel thrown overboard by the photographer. They need to be fast: once the food source becomes widely known, it's every gannet for itself.

"Gannets are masters of flight, but they're also efficient hunters below the water," says Dr Ewan Wakefield, a biologist at the University of Glasgow. "They have eyes which function well above and below water, and bodies protected by air sacs which can compress on impact with water, allowing them to plunge dive into the sea."

"Gannets from different colonies tend to forage in mutually exclusive areas," he continues. "If a bird has flown a smaller distance, it's going to be in better condition than a bird from a more distant colony."

PHOTO: RICHARD SHUCKSMITH/NPL



EYE OPENER

All fired up

NAIROBI,
KENYA

In November last year, some 5,250 seized firearms were arranged into three 4.5m-high piles, before being doused with fuel and set alight by Kenyan authorities. The bonfire, which took place near Nairobi, was attended by the country's deputy president William Ruto. It is hoped that the blaze will deter people from owning firearms and encourage others to surrender their weapons.

Kenyan gun laws are strict, and residents have to go through a number of controls and checks to own a firearm. Despite this, hundreds of guns are smuggled into the country each year, particularly via the border with neighbouring Somalia. It is estimated that around half a million guns are illegally held by civilians in Kenya, and are used for poaching, robberies and extremist violence.

PHOTO: CAMERA PRESS/DAI KUROWAKA

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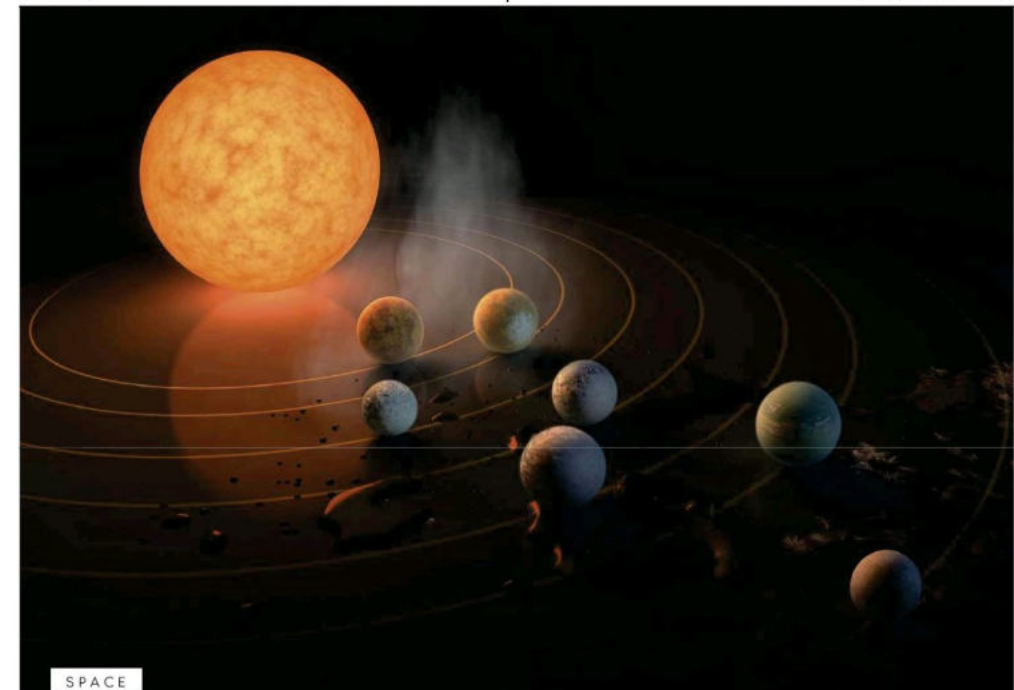
good energy

DISCOVERIES

DISPATCHES FROM THE CUTTING EDGE

APRIL 2017

EDITED BY JASON GOODYER



SPACE

SEVEN EARTH-SIZED EXOPLANETS FOUND

The system of planets found orbiting nearby dwarf star TRAPPIST-1 may be our best chance yet of finding alien life

TRAPPIST-1, an ultracool dwarf star located just 40 light-years from Earth in the Aquarius constellation, was first detected by researchers from Liege using the Transiting Planets and Planetesimals Small Telescope (TRAPPIST) in Chile, and later confirmed by NASA's Spitzer Space Telescope and the Very Large Telescope, also in Chile.

The planets were detected by observing dips in the star's light output caused by each of the seven planets passing in front of it, events known as transits.

The researchers found that all of the planets are comparable in size to the Earth, while density measurements suggest that the innermost six are rocky.

Current climate models suggest the three innermost planets are probably too hot to support liquid water, and the one furthest from the star is too cold. However, the remaining three sit comfortably within the habitable zone and could host oceans of surface water – a feature thought to be essential for the existence of life.

"The energy output from dwarf stars like TRAPPIST-1 is much weaker than that of our Sun. Planets would need to be in far closer orbits than we see in the Solar System if there is to be surface water," said researcher Dr Amaury Triaud. "Fortunately, it seems that this kind of compact configuration is just what we see around TRAPPIST-1."

PHOTO: NASA



EXPERT COMMENT

The star is relatively small, just 8 per cent the mass of the Sun, and would appear to glow salmon pink when observed from the surface of the planets, the researchers say.

Now that astronomers know that the planets are there, the next job is to find out what they are really like. The first step is to make an accurate determination of their densities. When searching for habitable worlds, rocky planets are the clear preference because – put simply – they provide a surface for life forms to walk, slither or otherwise move across.

The European Space Agency (ESA) will launch CHEOPS (CHAracterising ExOPlanet Satellite) in 2018. The main science goals of the mission are to measure the densities of planets with radii between one and six times of Earth. The TRAPPIST-1 system will be high on the list.

The next step will be to analyse the planets' atmospheres to see if any look like they could be habitable. "The main goal will be trying to detect the signature of water," said CHEOPS scientist Dr Vincent Bourrier.

Water vapour in a planet's atmosphere could betray widespread oceans and a water cycle. Its signature appears in the infrared region of the spectrum and this is where the NASA-built James Webb Space Telescope (JWST) comes in.

ESA will launch the JWST in the same year as CHEOPS. With its 6.5m-diameter infrared mirror, JWST will make analysing exoplanet atmospheres easier than ever. One of its first targets is likely to be the seven worlds of the TRAPPIST-1 solar system.

"ROCKY
PLANETS ARE
THE CLEAR
PREFERENCE
BECAUSE THEY
PROVIDE A
SURFACE FOR
LIFE FORMS"

While finding water vapour would increase the belief that the planet under investigation is potentially habitable, there are other factors that could affect a planet's ability to support life.

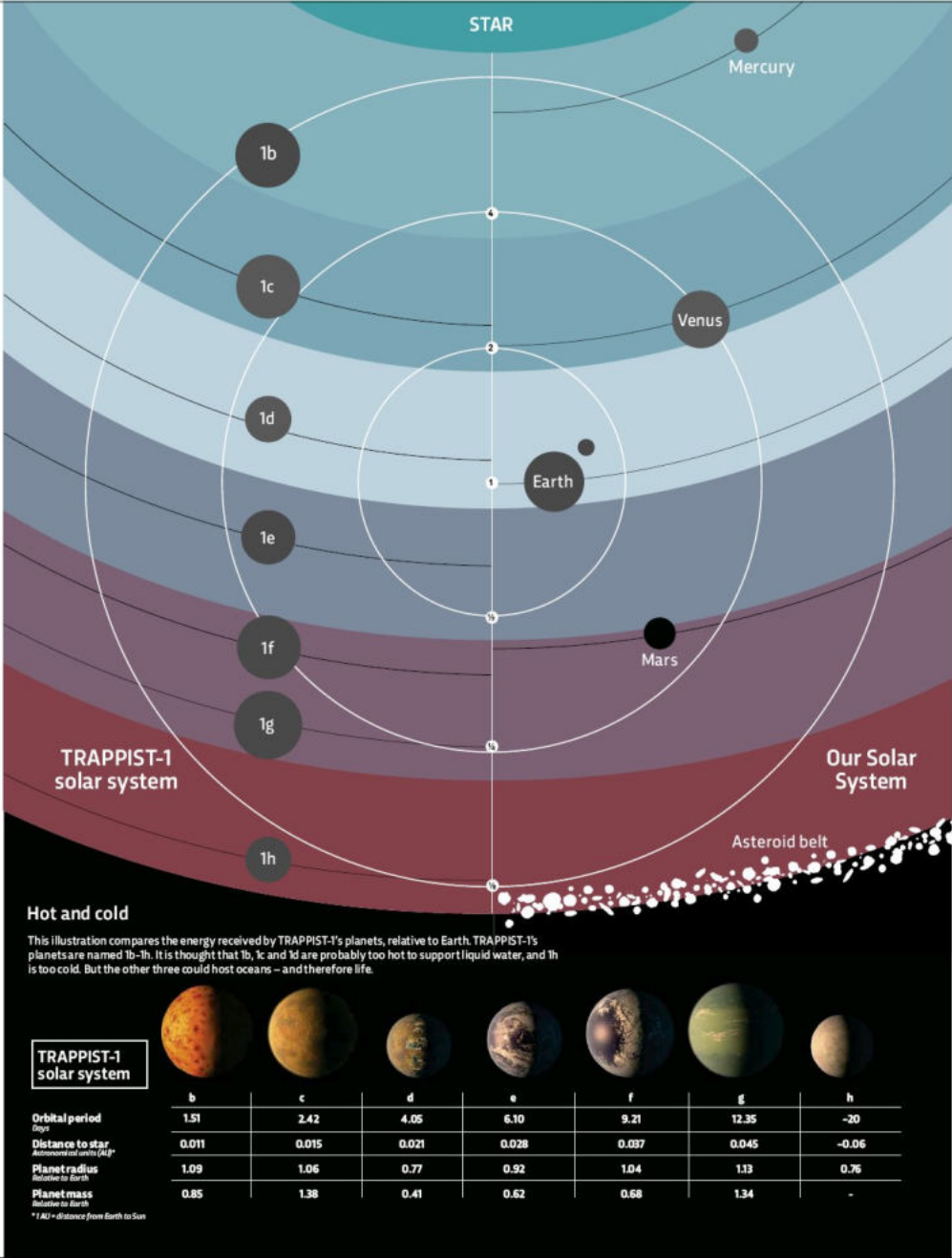
To investigate those, Bourrier and his team have already used the Hubble Space Telescope to look at the ultraviolet signature of TRAPPIST-1's two innermost planets. His work shows that those planets could have had their atmospheres completely eroded away by the radiation from the star – rendering the planets barren. Could this have happened to the other worlds of TRAPPIST-1?

Actually proving that a planet is habitable may be really tough. Astronomers will have to look for 'biomarkers'. These are gases that only exist together in an atmosphere because they are being replenished by the metabolisms of living creatures. Oxygen and methane are good examples in our own atmosphere. So far, there are no firm plans to build a space telescope capable of making such an exacting measurement, although NASA and ESA have both studied engineering concepts.

NASA's next exoplanet mission, the Transiting Exoplanet Survey Satellite (TESS), also launching next year, could reveal many more solar systems like TRAPPIST-1. This mission will survey 200,000 stars and is expected to discover thousands of exoplanets, from the size of Earth up to Jupiter and larger."

Stuart Clark is an astronomy writer. His most recent book is the *The Search For Earth's Twin* (E20, Quercus).

PHOTOS: NASA X3



THE DOWNLOAD

HANDLE

What's so interesting about handles?

Ah, not handle but Handle – the latest robotic creation to come out of the Boston Dynamics development labs.

Hang on. Who are Boston Dynamics?

An engineering and robotics design company based in the US who are responsible for the impressive walking robots such as Big Dog and Atlas.

Right. What's so special about Handle then?

As it has a combination of both wheels and legs, it can travel over varied terrain. It has a top speed of 14km/h (9mph), it can make vertical jumps of up to 120cm and can pick up and carry loads as heavy as 50kg. It's also able to travel up to 24km on a single battery charge.

Impressive. So what can it be used for?

So far Handle is just being used for R and D purposes, but the future uses could range from everything from unloading lorries to search and rescue.



Boston Dynamics' rolling, jumping robot

ZOOLOGY

FOOTBALLING BEES SHED NEW LIGHT ON INSECT INTELLIGENCE

We bet these guys are good on the wing: bumblebees have been taught to play football by a team at Queen Mary University of London.

The team trained the bees to dribble a ball into a round goal in three different ways: some observed a previously trained bee scoring a goal, some watched the ball being moved into the goal by a magnet, and others simply 'found' the ball in the goal. The bees

were rewarded with a sugary treat for a successful 'shot'.

Of the three, those observing other bees learnt the quickest.

"Our study puts the final nail in the coffin of the idea that small brains constrain insects to have limited behavioural flexibility and only simple learning abilities," said

"BUMBLEBEES, ALONG WITH MANY OTHER ANIMALS, MAY HAVE THE COGNITIVE CAPABILITIES TO SOLVE COMPLEX TASKS"

researcher Prof Lars Chittka.

Further tests showed that the bees were able to apply their 'training' to various situations, such as balls placed in different locations and balls coloured differently.

"It may be that bumblebees, along with many other animals, have the cognitive capabilities to solve such complex tasks, but will only do so if environmental pressures are applied to necessitate such behaviours," said researcher Dr Olli J Loukola.



The bees' team colours are yellow and black

PHOTOS: CANAL/UNIVERSITY OF DUNDEE; K2 LIDA LOUKOLA

ANTHROPOLOGY

FACE OF BRUTALLY MURDERED PICTISH MAN RECONSTRUCTED

This handsome chap may look like an East London hipster who knows his espresso ristretto from his latte macchiato, but he was actually a Pictish man who lived in the Scottish Highlands 1,400 years ago.

This mug shot was digitally reconstructed from a skeleton found buried in a cave in Black Isle, Ross-shire by researchers from the University of Dundee.

The body was arranged in a cross-legged position with large stones placed on its legs and arms. Several severe fractures in the man's skull suggest he was brutally murdered before being laid to rest.

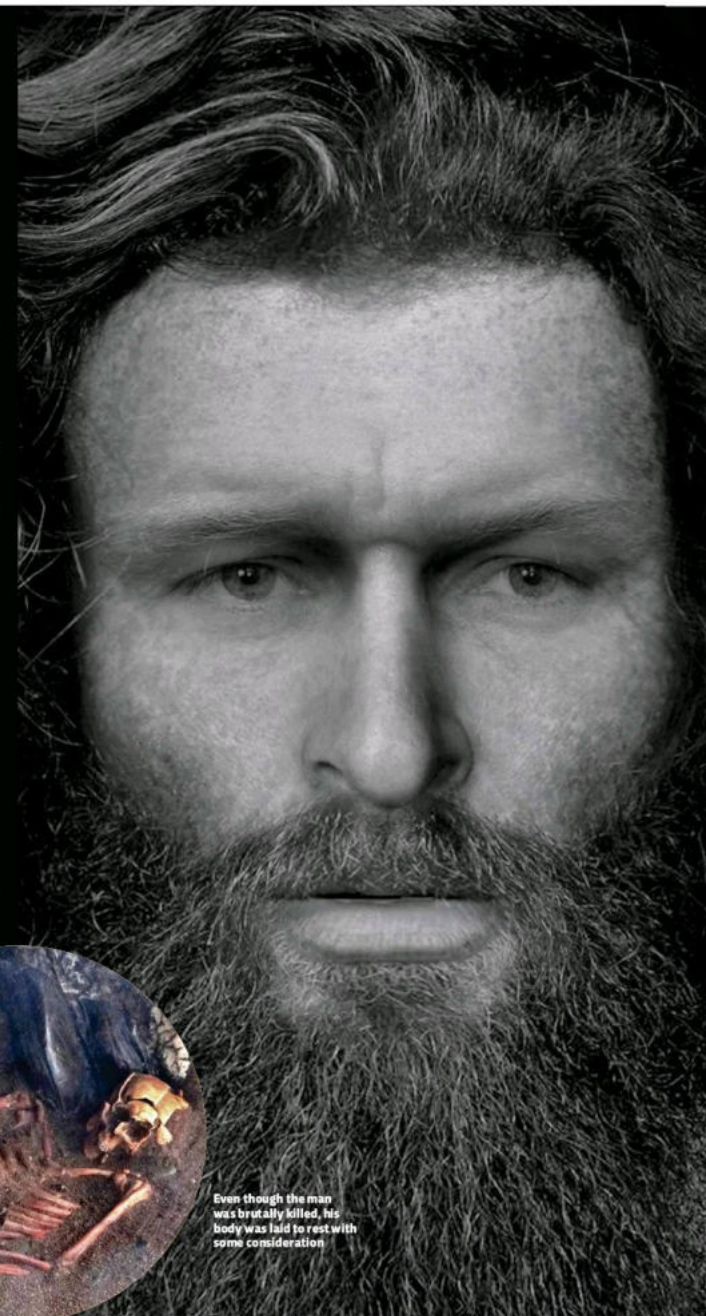
"This is a fascinating skeleton in a remarkable state of preservation which has been expertly recovered. From studying his remains we learned a little about his short life but much more about his violent death," said researcher Sue Black. "As you can see from the facial reconstruction he was a striking young man, but he met a very brutal end, suffering a minimum of five severe injuries to his head."

Radiocarbon dating indicates that the man died sometime between 430 and 630 AD. The remains were surrounded by evidence of iron smithing from around the same period and suggestions of more recent leather working.

Ongoing analysis of the skeleton and artefacts from the cave is expected to offer additional details of the man's place of origin and significance, as well as provide more information about the cave's archaeological and historical importance.



Even though the man was brutally killed, his body was laid to rest with some consideration





Artificial muscles made of woven fabric could be sewn into clothes to help disabled people get about more easily

MEDICINE

'KNITTED' MUSCLES COULD HELP THE DISABLED WALK AGAIN

Your woolly jumper may soon do more than keep you warm: Swedish researchers have created 'textile muscles' that could potentially be stitched into the clothes of injured or disabled people to enable them to move more easily.

"Enormous and impressive advances have been made in the development of exoskeletons, which now enable people with disabilities to walk again. But the existing technology looks like rigid robotic suits," said researcher Edwin Jager. "It is our dream to create exoskeletons that are similar to items of clothing, such as running tights that you can wear under your normal clothes. Such a device could make it easier for older persons and those with impaired mobility to walk."

The material is made by coating regular fabric with a fluid capable of conducting electricity.

IT IS OUR DREAM TO CREATE EXOSKELETONS THAT ARE SIMILAR TO ITEMS OF CLOTHING"

When a low voltage is applied to the fabric, the fibres from which it is made increase in length. By carefully controlling the knitted structure of the fabric, the researchers are able to create what they call "knitted muscles".

"If we weave the fabric, for example, we can design it to produce a high force. In this case, the extension of the fabric is the same as that of the individual threads," said researcher Nils-Krister Persson. "But what happens is that the force developed is much higher when the threads are connected in parallel in the weave. This is the same as in our muscles."

So far, the textile muscles have only been used in a simple robot device to lift a small weight. The next step is to integrate them into items of clothing, the researchers say.

PHOTO: THOR BALMÄDER/UNICORN UNIVERSITY, ARTWORK BY CHRIS GASKIN, COPYRIGHT GEOLOGY MUSEUM, UNIVERSITY OF OTAGO, ILLUSTRATIONS: DANIEL BRIGHT

PALAEONTOLOGY

GIANT PENGUINS MAY HAVE ROAMED THE EARTH ALONGSIDE DINOSAURS

Here's one penguin you definitely wouldn't want to p-p-pick up! Researchers have discovered a 61-million-year-old fossil belonging to a Waimanu – a giant penguin that stood 1.5m (4ft 11in) tall.

The fossil was unearthed near the Waipara River in New Zealand's Canterbury region, and dates back to the Palaeocene era. The bones differ significantly in structure from other Waimanu fossils discovered from the same period, indicating that there was a great deal of diversity amongst them. This could mean the evolution of penguins started much earlier than previously thought, perhaps even during the age of dinosaurs.

"This shows that penguins reached an enormous size quite early in their

evolutionary history, around 60 million years ago," said researcher Gerald Mayr. "What sets this fossil apart are the obvious differences compared to the previously known penguin remains from this period of geological history."

"The leg bones we examined show that during its lifetime, the newly described penguin was significantly larger than its previously described relatives," Mayr continued. "Moreover, it belongs to a species that is more closely related to penguins from later time periods."

The animal also likely differed from its more primitive relatives in another key way: it moved with the upright, waddling gait characteristic of modern penguins.

Prehistoric penguins were much larger than the birds we know and love today



POETRY LOVERS

Knowing your rhyming couplets from your iambic pentameter is good for you. Listening to the specific rhythms of poetry can trigger positive feelings in listeners' brains, researchers at Bangor University have found.

BIRDWATCHERS

It's time to dust off the binoculars. Indulging in a relaxing spot of birdwatching can make us less anxious and depressed, researchers at the University of Exeter have found.

GOOD MONTH

BAD MONTH

INTERNET TROLLS

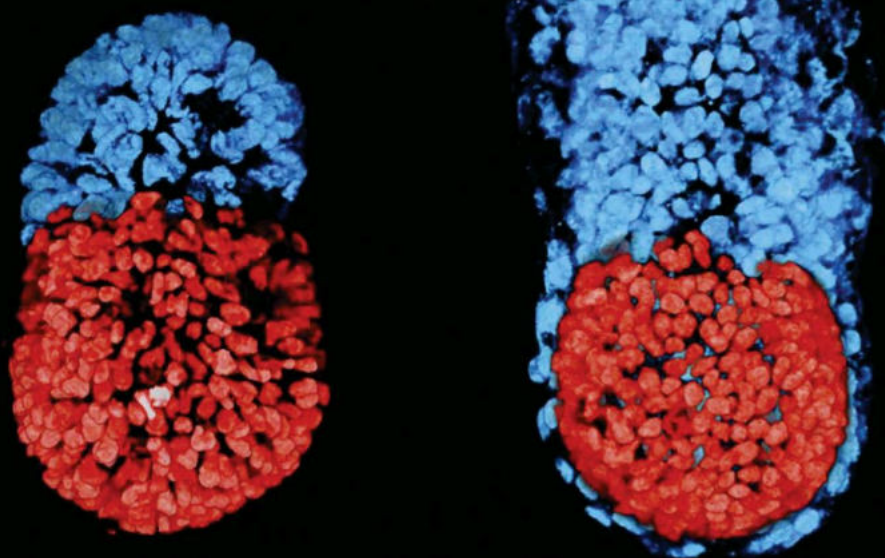
Like posting nasty comments online? It might be time to get back under your bridge: Google has started trialling a comment-policing AI to sift through internet forums and remove toxic posts.

TATTOO ARTISTS

Getting inked up can be just as painful for the artist as the client. A team at Ohio State University has found that the long working hours and poor posture that are typical for tattoo artists can lead to headaches and chronic back pain.



The mouse embryo at different stages of development, with embryonic stem cells (red) and trophoblast stem cells (blue)



BIOLOGY

MOUSE EMBRYO CREATED FROM STEM CELLS FOR THE FIRST TIME

By using two different types of stem cell, researchers at the University of Cambridge have successfully built an artificial mouse embryo in the laboratory – a breakthrough that may help us understand why two out of three human pregnancies fail during the early stages.

Our knowledge of early embryo development is still quite hazy, partly because of the strict rules around research involving real-life human embryos. The technique pioneered in Cambridge involves bringing together two types of stem cell: the embryonic stem cells (ESCs) that will go on to form the mouse's body, and the trophoblast stem cells (TSCs) that will go on to form the placenta.

The scientists placed both types of cell onto a 'scaffold' called an extracellular matrix, and observed how they then organised themselves just

as they would in a real-life embryo, with ESCs at one end and TSCs at the other. Because the third type of stem cell involved in the natural process – the endoderm stem cells that form the 'yolk sac' – was not present, the resulting embryos are not able to develop into actual mice.

Previous attempts to create embryos in the lab using only ESCs all failed, but it's hoped this breakthrough will lead to the creation of new avenues for embryo research.

"We are very optimistic that this will allow us to study key events of this critical stage of human development without actually having to work on embryos," said researcher Prof Magdalena Zernicka-Goetz. "Knowing how development normally occurs will allow us to understand why it so often goes wrong."

PHOTOS: SARAH HARRISON & GAILLE RECHER/ZERNICKA-GOETZ LAB/UNIVERSITY OF CAMBRIDGE, TRIP/UCSD

ANTHROPOLOGY

ROYAL MAYAN PENDANT POSES ANTHROPOLOGICAL PUZZLE

This is bling fit for a king. A piece of carved jade jewellery discovered by archaeologists in what is now central Belize has raised new questions about the Mayan civilisation that ruled Central America from around 2000 BC until the Spanish colonisation.

The pendant was unearthed at Nim Le Punit, some 40km north of the town of Punta Gorda, in 2015. Nim Le Punit, which was discovered in 1976, is known to have been a Mayan settlement between 150 and 850 AD, in keeping with the pendant's estimated creation date of around 670 AD.

However, it was believed to be a village of relatively low importance, lying on the outskirts of the Mayan empire. And yet the T-shaped pendant clearly belonged to a

member of the royal family; not only is it exquisitely crafted from a precious stone, but there are raised hieroglyphs on the back which say as much. These tell us that the pendant was made for King Janaab' Ohl K'inich, who ascended to the throne in 647 AD, while inscriptions on the walls of the 9th-Century tomb in which it was found show the priest-king wearing the pendant in incense-scattering ceremonies.

So what were the king and his pendant doing in lowly, outlying Nim Le Punit, and why was the pendant buried in a tomb at all? It's as though an ancient British crown had mysteriously surfaced in a small fishing village in Devon, and archaeologists now intend to investigate further.



The hieroglyphs on the pendant say that it was made for the Mayan king Janaab' Ohl K'inich

IN NUMBERS

3
million

The number of people in the UK who suffer from colds and flu every winter thanks to vitamin D deficiency, according to a study by a team at Queen Mary University of London.

2
HOURS

The average time a wild African elephant spends sleeping per day – the least amount of any mammal studied to date.

12

The number of antibiotic-resistant superbugs named by the World Health Organization as posing a threat to human health.



FOSSILS

WORLD'S OLDEST FOSSIL HINTS AT ORIGIN OF LIFE ON MARS

This rock could host the remains of one of the oldest life forms on Earth. A team from University College London has discovered fossils of iron-eating microorganisms at least 3.7 billion years old encased in layers of quartz in Nuvvuagittuq Supracrustal Belt (NSB), Quebec, Canada.

The NSB contains some of the Earth's oldest sedimentary rocks that probably formed part of an iron-rich deep-sea hydrothermal vent system that provided a habitat for the planet's first life forms.

"Our discovery supports the idea that life emerged from hot, seafloor vents shortly after planet Earth formed," said researcher Matthew Dodd. According to Dodd, this rapid appearance of life on Earth fits in with other evidence of recently discovered 3.7-billion-year-old

sedimentary mounds that were shaped by microorganisms.

The fossils are similar to the iron-oxidising bacteria that are found near hydrothermal vents today. They were discovered alongside other minerals which are found in biological matter and are frequently associated with fossils.

The organisms date back to a time when there was also liquid water present on Mars, suggesting that the Red Planet may have hosted life too. "These discoveries demonstrate life developed on Earth at a time when Mars and Earth had liquid water at their surfaces, posing exciting questions for extraterrestrial life," said Dodd. "Therefore, we expect to find evidence for past life on Mars four billion years ago, or if not, Earth may have been a special exception."

MAIN IMAGE: This rocky outcrop where the fossils were found may once have been part of a system of hydrothermal vents

INSET IMAGE: The tiny fossils contain tubules, formed by ancient bacteria

PHOTOS: D. PARNIEAU / YALE UNIVERSITY; ILLUSTRATION: DAN BRIGHT

SPACE

MOST DETAILED MAP OF DARK MATTER CREATED

It's dark matter as we've never seen it before: a team from Yale University has put together one of the highest resolution maps of the elusive particles by using images from the Hubble Space Telescope to study three clusters of galaxies.

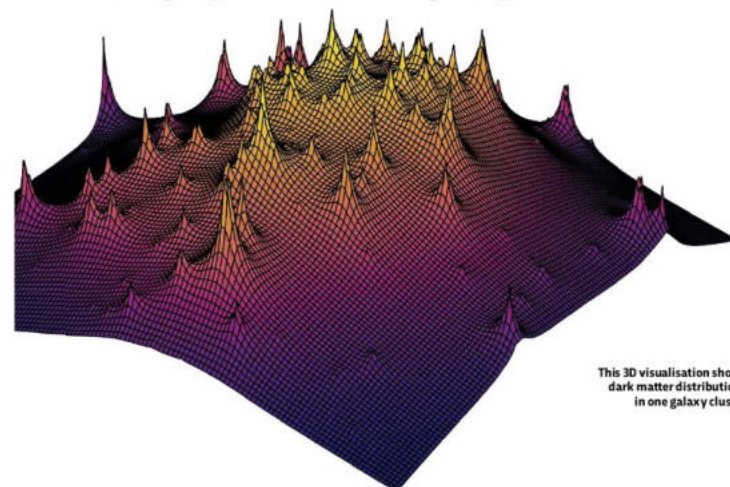
Dark matter is a theorised substance that doesn't reflect or absorb light and is thought to comprise 80 per cent of the matter in the Universe. It can only be detected indirectly through its gravitational effects.

Dark matter particles are thought to provide the unseen mass that is responsible for a phenomenon known as gravitational lensing, by bending light originating from distant galaxies. This light bending produces distortions in the shapes of galaxies viewed

through the 'lens'. The team decoded these distortions to create the map of dark matter.

"With the data of these three lensing clusters we have successfully mapped the granularity of dark matter within the clusters in exquisite detail," said researcher Prof Priyamvada Natarajan. "We have mapped all of the clumps of dark matter that the data permit us to detect, and have produced the most detailed topological map of the dark matter landscape to date."

They found that the map closely matches computer simulations of dark matter theoretically predicted by the cold dark matter model – dark matter that moves slowly compared to the speed of light.



This 3D visualisation shows dark matter distributions in one galaxy cluster

THEY DID WHAT?!



'SURROGATE' HENS BRED TO LAY OTHER CHICKENS' EGGS

What did they do?

A team at Edinburgh's Roslin Institute used gene-editing tools to knock out the DDX4 part of hens' genomes to create hens that are unable to produce their own eggs but are otherwise healthy.

Why did they do that?

For the next step, the researchers want to implant the hens with primordial germ cells – cells that lead to the production of eggs – from other breeds of chicken, enabling them to produce eggs of this other breed.

What do they want to do that for?

In the short term, the researchers hope that the technique can be used to protect rare breeds of poultry, but it could also be used to breed hens that can lay the eggs of other bird species in a bid to help conservation efforts.

Robinmore's night frog is tiny enough to crouch on a coin



ZOOLOGY

TINY NEW FROG SPECIES FOUND IN INDIA

This little guy belongs to one of seven new frog species that were recently found hopping among the fallen leaves in the forests of India's Western Ghats mountain range by researchers at the University of Delhi.

Part of the genus *Nyctibatrachus*, more commonly known as night frogs, four out of the seven amphibians discovered are less than 15mm in length – small enough to perch on a human thumbnail.

Despite being new to science, the frogs are relatively common in their local areas. "In fact, the miniature species are locally abundant and fairly common, but they have probably been overlooked because of their

extremely small size, secretive habitats and insect-like calls," said Sonali Garg, a researcher who worked on the project.

The frogs were classified using DNA studies and are part of an ancient genus of frogs that diversified on the Indian landmass approximately 70–80 million years ago. However, due to their close proximity to humans, several of them are facing extinction.

"Over 32 per cent, that is one-third of the Western Ghats' frogs are already threatened with extinction. Out of the seven new species, five are facing considerable anthropogenic threats and require immediate conservation prioritisation," said lead researcher SD Biju.

PHOTO: SD BIJU

WHAT WE LEARNED THIS MONTH

LIFE EXPECTANCY SET TO EXCEED 90 FOR FIRST TIME

A study by researchers in London has found women in South Korea will live to an average of 90 by 2030.

FISH CAN 'SING' LIKE BIRDS

Step aside Lady Gaga – fish have been recorded 'singing' by researchers in Western Australia. The aquatic symphonies occur at dawn and dusk, much like the choruses sung by birds.

BUTTERCUPS' GLOW IS CAUSED BY THEIR PETAL STRUCTURE

Ever held a buttercup under your chin to see if you like butter? The signature glowing effect is caused by an incredibly thin outer layer acting like an optical film and reflecting light, Dutch researchers have found.

FIVE A DAY MAY NOT BE ENOUGH

A team at Imperial College London estimates that nearly eight million early deaths could be prevented worldwide if we all ate 10 portions of fruit and veg a day. Pass the carrot sticks.



WHAT CAN WE LEARN FROM 'HIDDEN FIGURES'?

Gender and racial equality still have a long way to go

"THE WOMEN THEMSELVES WERE ALWAYS VERY MODEST ABOUT THEIR EFFORTS"

Having been a kid during the Space Race of the 1960s, I've always reckoned myself something of a space buff. While still in short trousers I could reel off the names of all the astronauts and cosmonauts and their achievements. But I must confess the story behind the hit movie *Hidden Figures* came as a complete surprise.

Was it really possible that NASA had used rooms full of people to work out rocket trajectories and orbits by hand? And not just any people, but teams of mathematically gifted African-American women – at a time when discrimination on the basis of ethnicity and gender were rampant?

The story of how Katherine Johnson and her fellow "colored computers" – as they were known at NASA in the early 1960s – helped America win the Space Race is truly inspiring in both human and scientific terms. Each day, Johnson and her colleagues tackled mathematical problems of mind-bending complexity while simultaneously dealing with routine sexism and racism.

Yet despite all of the hardships they faced, the quality of their work was such that when John Glenn, the first American into orbit, was given his flight details worked out using an IBM computer, he insisted on having them personally re-calculated by Johnson – just to be sure.

So how come the story of Johnson and her colleagues has remained hidden for so long? According to author Margot Lee Shetterly, author of the eponymous book on which the movie is based, part of the reason is that much of their work was secret.

The booster rockets that were used to put the first US astronauts into space were essentially just modified ballistic missiles, which had originally been designed to lob thermonuclear weapons at the Soviets. As such, their range, acceleration and other characteristics needed to make trajectory calculations were classified. But as Shetterly researched her book, she found other reasons for the role of NASA's human computers remaining hidden – reasons that are hard to fathom today.

The mere fact that they were female meant their work was largely viewed as just a higher form of 'chore' women were supposedly naturally good at. Then there was the effect of the racial segregation in US military and federal institutions of that era, which even dictated who Johnson and her colleagues were allowed to sit next to in the work canteen. With so few beyond their own circle to talk to, it's hardly surprising their heroic efforts remained unsung.

Perhaps most telling of all, however, is the fact that the women themselves were always very modest about their efforts. As Shetterly told *BBC History* magazine in a recent interview, when Johnson and her former colleagues learned their stories would be told in a book and a movie, their reactions was: "What's the big deal?"

Yet at the same time, they knew they had never got the accolades they deserved. This will seem utterly paradoxical – especially to those of us known as 'men'. From the first time we successfully use a potty, we males tend to be very keen on making sure everyone knows of our achievements. But women... not so much.

And no, it's not just me saying that.

Research shows that women are less likely than men to put themselves forward for promotion, often because they think that if they just keep doing great work, someone will surely notice eventually. That's a big mistake – and one that benefits pushy blokes with no qualms about bragging to the boss.

In *Lean In*, her celebrated study of leadership, Facebook's chief operating officer Sheryl Sandberg cites this phenomenon as a key reason why women are under-represented at the top of their professions. *Hidden Figures* does a grand job of showing the feistiness and determination of Johnson and her colleagues in helping America win the Space Race. But anyone who thinks women would find it all less of a struggle today is living on another planet. 🌌

Robert Matthews is visiting professor in science at Aston University, Birmingham.



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EDITED BY RUSSELL DEEKS



TOP OF THE RANGE

Meet the Range Rover Velar. Unveiled at the London Design Museum this month, its parent company Land Rover says this car's aesthetic is an exercise in reductionism – every stray line has been tamed. This is most evident inside, where Land Rover's designers have been busy banishing buttons from the dashboard. The in-car hardware – a pair of high-definition screens – has been built by Panasonic. It offers a full touchscreen experience, and you can flick content

and controls between the screens in the car. Land Rover has kept haptic 'magic rings' inside to make it less distracting to control while you're on the move. We're also happy to see a non-leather interior made out of a new polyester/wool mix that the company says is as durable and easy to clean as its cow-based counterpart. And their most frugal engine will offer an impressive 52.5mpg, apparently. But we'll reserve our judgment until we test one later in the year.

WANTED!



GOODBYE, CRAMPS

LIVIA

Billed as “an off switch for menstrual pain”, Livia consists of the Livia device itself and two electrodes that you fix to your lower abdomen with gel stickers. Livia then directs a small electromagnetic current to the electrodes and sends pulses through the nerves, which its makers claim will block the signals that cause pain, without the use of drugs. There’s certainly a demand for it: Livia exceeded its Indiegogo funding target nearly 14 times over. It’s CE approved and currently awaiting FDA approval in the US. **\$149 (£120 approx), mylivia.com**

VR ON THE MOVE

LENOVO THINKPAD P71



The flagship in Lenovo’s new laptop range is this 17-inch model that’s designed not just to handle virtual reality content, but to create it too.

Generating VR content requires lots of processing grunt and disk space, so you’ll find four drive slots for HD/SSD storage, support for up to 64GB of RAM, Thunderbolt 3 ports

for connecting high-end peripherals and an optional 4K display, while its Xeon E3 processor is backed up by a 16GB Quadro P5000 graphics card. It is, in short, a beast – though if the price tag’s beyond you, Lenovo has also just released the Yoga A12, a hybrid Android tablet for a mere **£240. \$1,849 (£1,485 approx), lenovo.com**

POOCH PRYER

JAGGER & LEWIS SMART DOG COLLAR

Like a Fitbit for Fido, this smart device from Jagger & Lewis will track your dog’s behaviour and provide analytics via an accompanying app. It clips onto your dog’s collar, then tracks their body temperature, how far they’re walking,



how much they’re eating and drinking and how often they bark. This information is then correlated against your dog’s age and breed to alert you if something looks like it may be amiss. **£149, jagger-lewis.com**

A CLASSIC REBORN

NOKIA 3310

Nokia has just relaunched the 3310, its hard-wearing ‘candybar’ phone of the early noughties. Er, sort of. The new 3310 has a colour screen, 2MP camera, FM radio, GPS, SD card slot and 2.5G internet, so it’s not really the same phone, it just looks (a bit) like the old one. Its battery can manage 22 hours talk time and can run in standby mode for up to 31 days on a single charge, while that low price tag makes it ideal for using when you’re out and about. **£41, nokia.com**



A CLEARER PICTURE

LOGITECH BRIO

Whether you’re an avid vlogger or a serial Skype, there are plenty of reasons to ditch the basic webcam built into your laptop for something higher-spedd. And they don’t come any higher-spedd than Logitech’s new 4K offering, which is the first commercial consumer webcam to offer ultra high-definition video with high dynamic resolution. Note, though, you’ll need a Windows PC with a Kaby Lake processor to get the full benefit. **£199, logitech.com**



APP FEED



Blynk
Add smartphone control to projects that use an Arduino or Raspberry Pi. Just drag and drop widgets to build your device’s own app-based UI. **Free, iOS/Android**



Lego Life
This Instagram-like social network for under-13s lets kids share pictures of their creations without revealing their real names. **Free, iOS/Kindle Fire**



Sickweather
This is one for serious germophobes only. The app monitors references to illness on social media to create a real-time map of bug hotspots. **Free, iOS/Android**



EDITOR'S CHOICE



IT'S ALL IN THE WRIST

GAMEBAND

Email notifications and weather alerts are all very well, but wouldn't you rather be playing *Pong*? The makers of Gameband are certainly hoping so. It's a smartwatch with a 1.2GHz Snapdragon processor and a 1.63-inch AMOLED display that comes preloaded with 20 games. The Gameband itself runs on Android, but is compatible with both Android and iOS devices. **\$199 (£160 approx), gameband.com**



THE BLACKBERRY IS BACK

This year, nostalgia dominated Mobile World Congress – the largest mobile technology conference in the world. Companies vied for the public's attention with the likes of 5G networks, autonomous racing cars and smart wearables, but the undeniable stars of the show were two rehabilitated gadgets from the past: the Nokia 3310 (turn to p29) and the BlackBerry KEYOne.

You'd be forgiven for thinking that BlackBerry had been consigned to the big tech rubbish heap in the sky, along with the likes of Palm Pilots and Google Glass. But the BlackBerry brand was recently bought by Chinese company TCL, which wants to resurrect the device for the surprising number of people who still pine after diminutive physical keyboards on their smartphones.

The device isn't on sale yet, so we can't offer full judgment, but we can say that it seems like the phone's aimed at the business users that made BlackBerry so

popular in the first place. The qwerty keyboard doubles as a giant trackpad, letting you browse the web with touch gestures. Meanwhile, its keys can be programmed to launch apps and there's a fingerprint sensor built in to the spacebar. Since security is important for a work phone, the KEYOne comes loaded with software called DTEK, which is supposed to constantly monitor for security threats – BlackBerry claims it'll be the most secure Android device in the world.

Yep, that's right, the phone runs on Android. This is in contrast to most recent BlackBerry iterations, which were bereft of apps due to its own-brand operating system. The phone's hardware is on par with most current Android phones and it'll hold the same great camera found in Google's Pixel phone. Out at the end of April, the KEYOne probably won't have us giving up our iPhones or Google Pixels any time soon, but it will appeal to the company's cult across Europe.

NEWS BYTES

DELIVERY BOTS ARE GO

The state of Virginia, US, has just legalised delivery robots, as long as the tiny trucks don't weigh more than 23kg, or travel faster than 16km/h. They expect shops to offer autonomous home deliveries within 3.2km.



SLEEP EASY

Sleep trackers could actually harm, not help, your sleep quality. 'Orthosomnia', aspiring to a perfect night's sleep, could become an unhealthy preoccupation, according to a report in the journal *Sleep Medicine*.

THIS PHONE WILL SELF DESTRUCT...

A device that crushes crucial chips in your phone has been developed by researchers at the King Abdullah University of Science and Technology. The mechanism could be applied to most modern devices and can be triggered remotely as a last resort.

OCULUS RIFT PRICE DROP

The pioneering VR headset just got \$200 cheaper (£162) after slow initial sales. Meanwhile, the PSVR has sold over a million units, way ahead of its six-month target.



ROBOTS

Cute robot porter

Gita is a prototype robot from Piaggio Fast Forward – part of the same group that makes Vespa scooters – that acts as your own personal porter. It stands 56cm tall, and is built to carry up to 18kg of supplies (that's a lot of crisps) inside its circular shell.

The robot can operate in one of two modes. In autonomous mode, it

navigates using GPS and onboard cameras; alternatively, you can strap on a camera-equipped belt and your trusty friend will follow you.

Sadly there's no word yet as to when, or even if, the Gita prototype seen here will go into full-scale production. But still, it'd make Saturday's supermarket trip a heck of a lot sweeter.

VIRTUAL REALITY

VR gets even more real

VR Sense is a virtual reality gaming cabinet from Koei Tecmo Wave. It features enhancements designed to turn VR into a multisensory experience, complete with a moving seat, realistic aromas, and weather and temperature effects.

If you play *GI Jockey Sense*, for instance, your seat will buck up and down like a real horse while you feel the wind and rain lashing on your face. Meanwhile, a version of Koei's flagship title *Dynasty Warrior* features "a realistic reproduction of hot flames covering the battlefield". But we're not sure we're brave enough to dive into survival game *Horror Sense*...

The cabinet is expected to find its way into Japanese arcades some time in the next year or two.



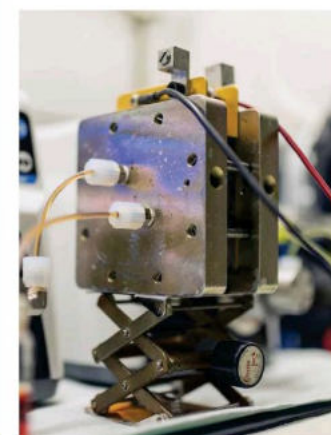
MATERIALS

Building better batteries

Two different batteries developed at Harvard and Pennsylvania State in the US could hold the key to better energy storage.

Both of the batteries aim to make energy storage more efficient and less environmentally harmful. Much of the current research focuses on 'flow cells' – a type of battery that can be recharged by simply replacing the electrolyte fluids inside – and it's this path that the Harvard team has gone down. The researchers have modified the molecular structure of the electrolytes so that they can be dissolved in water and are more resistant to degradation. The result is a liquid battery that can store energy for over 10 years, and that contains no toxic materials. It's hoped the battery will find applications in storing energy from wind turbines and solar panels.

Meanwhile over at Penn State, researchers have been experimenting with a flow cell battery whose two electrolyte solutions consist simply of solutions of CO₂ and normal air. The difference in pH balance is then used to generate an electrical current. The idea is that such a device could be fitted to coal- or oil-fired power stations and be used to reduce emissions while generating more energy.

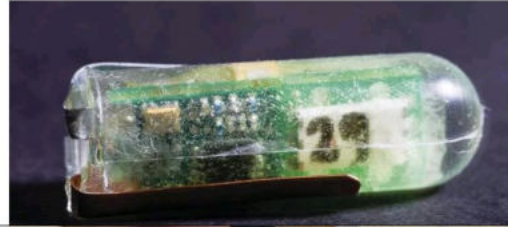


MEDICAL MARVELS

These five gadgets could make GPs lives easier in the near-future

1. BIO BATTERIES

Doctors increasingly use swallowable sensors to see what's going on inside a patient's body, but the problem is that to be safe, they can store only limited power, and therefore typically last just an hour or two before the batteries die. But a team at MIT has unveiled a new battery that harnesses the electrolytes in digestive fluids to generate current. Using one such battery, the team powered a temperature sensor for over six days as it passed through a pig's digestive tract.



2. LITTLE LABS

A microchip has been developed at Stanford University that can carry out over 20 diagnostic tests, such as isolating and identifying breast cancer cells and screening for various toxins. Best of all, it can be manufactured for less than a penny per unit. It's hoped the device could be used to provide better healthcare in developing countries where hospitals are scarce.



3. TINNITUS APPS

Tinnitus, or ringing in the ears, is associated with the brain's auditory cortex. Researchers at the Wyss Center for Bio and Neuroengineering in Geneva have developed a brain implant that enables the user to quieten the din by thought control alone. Signals are transmitted from the implant to the person's phone. To stop the tinnitus, the person concentrates on altering the display of a specialised app, changing the brain activity in the process.



4. AUTOFOCUS FOR YOUR EYES

Reading glasses and varifocals could soon be a thing of the past. A team at the University of Utah has demonstrated a pair of prototype glasses featuring an autofocus system that adjusts the focal length of the glycerine lenses, depending on the distance of the object you're looking at. The refocusing takes just 14 milliseconds, but the prototype is still quite clunky – the next step will be to make the glasses smaller and lighter.



5. ROBOTS THAT CARE

As the population gets older and robots get smarter, their use in care homes may become widespread. That fact hasn't gone unnoticed by Segway Robotics or MIT, who recently joined forces to host a 'hackathon' in Singapore. Over the course of three days, 75 teams competed to find ways in which Segway's Loomo robot could be modified for use in elderly care. The best ideas will be tested in Singapore, before hopefully being rolled out globally. Go-go gadget granny!



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MESSAGE OF THE MONTH

Something to chew over...

My wife has been close to attacking me at meal times recently due to the noises I make while eating. So it was interesting to learn (March, p17) that there is a name for her 'affliction' – misophonia.

So, in a similar vein to Helen Czerksi, I've been experimenting with certain foodstuffs to find out which cause the worst reactions. Loud foods like crisps surprisingly had no effect, yet eating chicken and the resulting 'clicking' noise between my teeth invoked a cataclysmic reaction. I would love to understand more about the science behind what causes the noises, why it makes my wife want to kill me and what foods should be avoided. Hopefully you can help save my marriage!
Paul Mellor, St Albans

☛ Misophones have their own unique triggers. For some it's crunchy crisps, others slurpy milkshakes. The noises are largely down to someone's mouth and tooth shape and chewing action, so short of chomping more softly there's not much you can do. Scientists are yet to come up with an effective treatment, so in the meantime I suggest you invest in some ear defenders and keep your wife away from the steak knives! – **Jason Goodyer**, commissioning editor

WRITE IN AND WIN!

The writer of next issue's *Message Of The Month* wins a **Spire tracker**. This health gadget tracks your steps and calories burnt, but also measures your breathing levels. It detects when you're stressed, and will offer exercises to help. **spire.io**



WORTH \$130

PHOTO: GETTY



Chomping and slurping noises fill some misophones with rage

Hawking hero

I am so glad you featured a timeline of Stephen Hawking's accomplishments (January, p22) as he was very important to me in my studies at university. I was studying politics and philosophy, but my education became much more rounded as a result of watching a show he was hosting on the BBC at the time. I wish him all the best for his health in his 75th year and beyond.
Claire Keogh, Dublin

Stinky problem

The article on the human microbiome (January) is a nice overview of our relationship to microorganisms, but it contains a significant error. When discussing the role of these organisms in the human gut, it states that methane is the smelly component of farts. Sorry, methane is odourless. It is for this reason that methyl mercaptan, an organosulphur compound that is easily smelled, is added to methane used as a fuel. The smell of farts is largely due to hydrogen sulphide, along with other odour contributors.
Kenneth Koutz, California

☛ You're absolutely right and we apologise for this error. Methane is a component of the gases released by gut bacteria that make up farts, but natural methane is indeed odourless and NOT the smelly component of farts. The pungent smell of farts comes from other gases in the mix, hydrogen sulphide being one of the smelliest along with methanethiol.

– **Mun Keat Looi**, science writer

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ON THE MOON

WORDS: Dr Stuart Clark



On 14 December 1972, Gene Cernan stood at the foot of the lunar landing module and said, "...I take man's last step from the surface, back home for some time to come – but we believe not too long into the future". He was the 12th person to walk on the Moon, and clearly anticipated a fairly prompt return. That was not to be, as ambitions – if not funding – turned towards Mars. No one has walked on the Moon since. Now the tide is turning. After years of interest in the Red Planet, the scientific and astronautical community is uniting behind a push to return to the Moon, both to continue the research that was started by the Apollo missions and to prepare for future exploration. We spoke to five leading voices from the worlds of astronomy, philosophy, science and technology to understand why we have to go back.



PROF
LEWIS DARTNELL

Astrobiologist,
University of Leicester, UK

"The only astrobiological reason that you might want to go to the Moon is that it perhaps preserves ancient rocks from the Earth that have been splashed up by big asteroid strikes. And here I would want to tip my hat to Ian Crawford, University of London, for these ideas.

The Earth is an active and dynamic place. That's important in the emergence of life and its long-term evolution over billions of years. Yet the planet's dynamism poses a problem when you are trying to find the earliest traces of life on Earth, because most of the planet's crust has been destroyed by plate tectonics [the shifting and recycling of the Earth's surface rocks].

The Moon, on the other hand, is a stable, static and even boring place in the sense of active processes. If there were a way to get ancient rocks from Earth up onto the Moon, they would stick around for a long time, as they wouldn't be eroded or destroyed by plate tectonics. This is where asteroid strikes come in. If chips of the Earth got blown off our planet and up into space, the Moon would sweep up that material and preserve it.

So it stands to reason that there are probably ancient Earth rocks on the Moon that could contain microfossils or chemical fossils that [would tell us about the origin of life on Earth].

The problem is that it is going to be quite hard to find these flecks of Earth. You might start looking for hydrated minerals, which are ubiquitous on Earth but very rare on the Moon.

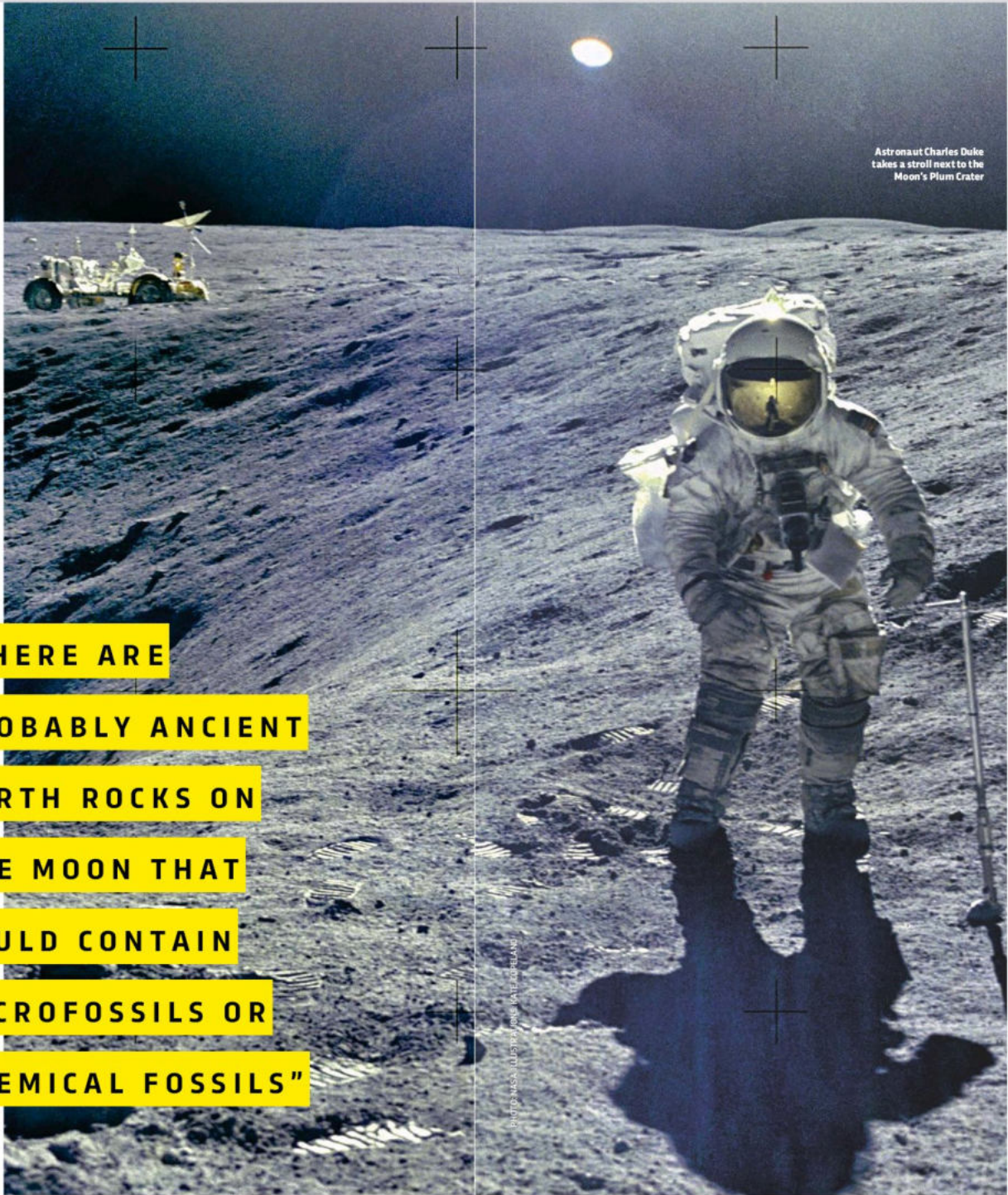
Any material splashed up would be distributed randomly across the Moon but you could look for places where the material has been preserved.

The main problem of preserving bio-signatures in space is the cosmic radiation. These high-energy particles travel at close to the speed of light, and are destructive when they hit cells of organic molecules. So we might want to target ancient lava flows on the Moon that may have covered up any Earth rocks that were lying on the surface at the time, and are now protecting them beneath several metres of rock.

There would be the issue of mapping to identify and date the lava flows, and then sending a mission to drill on a lava flow of the correct age.

It would be hard work. It would be like looking for a needle in a haystack without the use of a magnet. On the other hand, the pay-off would be enormous. You would be finding Earth rock that is far older than anything found on our planet. So there is a lot to gain from doing this."

"THERE ARE
PROBABLY ANCIENT
EARTH ROCKS ON
THE MOON THAT
COULD CONTAIN
MICROFOSSILS OR
CHEMICAL FOSSILS"



Astronaut Charles Duke
takes a stroll next to the
Moon's Plum Crater



NAVEEN
JAIN

Co-founder and chairman, Moon Express

"If I were to paraphrase John F Kennedy, 'We choose to go to the Moon, not because it is easy but because it is great business'.

When Moon Express lands on the Moon, we will become the first private company to do so. But more importantly, we become the fourth superpower to do so. That is quite symbolic of things to come. To me, the next set of superpowers are likely to be entrepreneurs, not nation states.

The time is now right to use technology to solve the grand challenges facing humanity. I argue that landing on the Moon could potentially bring world peace. We fight over land, water and energy, yet all we have to do is look up into space and there is an abundance of these things.

It is only a matter of time before we get hit by a massive asteroid. If we live only on Earth, then humans are going to become extinct like the dinosaurs. Wouldn't you prefer to have some entrepreneur creating an underlying infrastructure so that we can really become a multi-planet society?

What we will be doing is creating the underlying infrastructure of space. We think of ourselves as the iPhone of space. Nine-and-a-half years ago, Steve Jobs launched the iPhone and the App Store. Obviously he had a seriously good idea of what people could do with the device but no one imagined that the number one thing that people would use their iPhone for was to throw birds at pigs [the *Angry Birds* game]. But that's exactly what people did and it took seven years until something else captured the imagination of humanity and that was *Pokémon Go*.

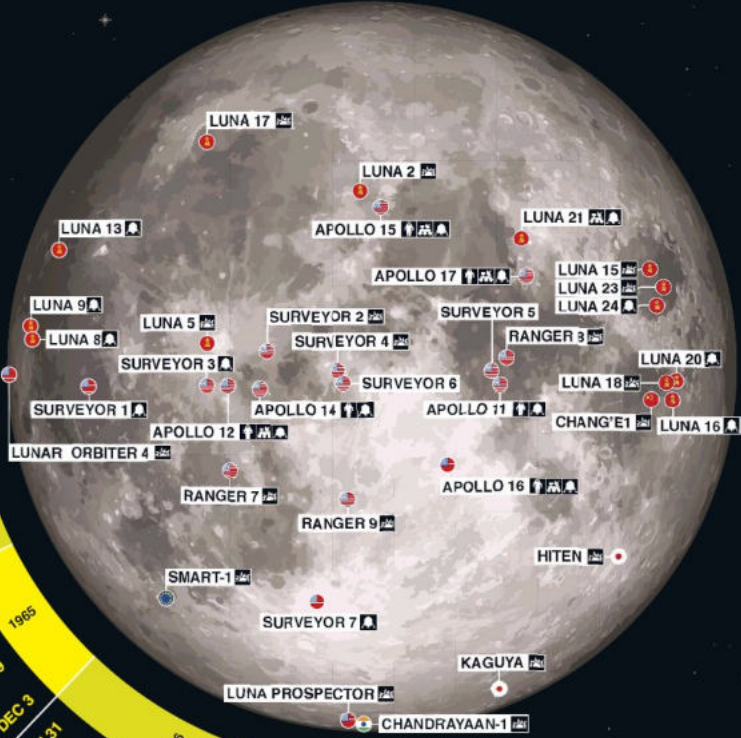
Now that we have created this iPhone of the Moon with Moon Express, we have to ask ourselves what is going to be the *Pokémon Go*. Will that be something that Moon Express will create, or is that something that we will allow other entrepreneurs to do? It could be bringing stuff down to Earth, or using stuff to create habitats on the Moon.

My gut reaction is bringing the lunar rocks to Earth could be the most beneficial task initially. We could disrupt the diamond industry. Diamonds were never the symbol of love and romance until the 1950s. De Beers created a brilliant campaign to sell that idea. If you are an entrepreneur against a monopoly you don't fight them, you change the game. So, we bring back the Moon rock and we change the paradigm: it's not enough to give her a diamond, if you love her enough you give her the Moon."

MISSIONS TO THE MOON

TIMELINE

[NEAR SIDE OF MOON]



Spacecraft Launch date

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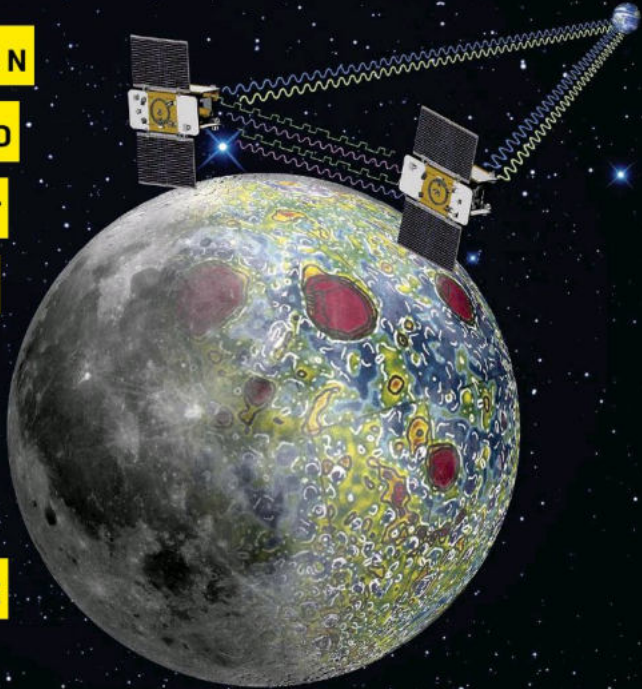
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"I WAS A KID WHEN
APOLLO HAPPENED
AND I THOUGHT IT
WAS THE FUTURE,
I THOUGHT THAT
WAS WHAT WE
WERE GOING TO
BE DOING: PEOPLE
IN SPACE"



PHOTOS: NASA/2



PROF DAVE ROTHERY

Professor of planetary geosciences,
Open University, UK

"Lunar exploration has been going on fairly vigorously for 20 years. We have a series of missions around the Moon: there's the GRAIL gravity mission from NASA; the Chinese are planning to go to the far side of the Moon; and there are plans from [private company] Lunar Mission One to go to the South Pole-Aitken basin to drill into that. So the unmanned exploration is happening but there's only so much you can do from orbit.

You do need to get among the surface materials as well – both for seeing the geology at close quarters, and for taking measurements that you cannot take from orbit. Apollo left four seismometers on the Moon for recording

moonquakes. They weren't brilliant but it's the only other planetary body that we've got seismology for. They told us about the Moon's interior but they were turned off after a few years – stupidly to save money.

A few seismometers on the lunar surface would give us great insight into the Moon's interiors. But you have to be on the surface to deploy them so that you can couple them properly to the ground.

And there are heat flow experiments. We don't know at what rate the Moon's internal heat is leaking out towards the surface. They tried to measure it on Apollo and it didn't work. They had trouble getting a good hole into the ground. So we are guessing at the lunar heat flow until we can go back, drill a hole and put some equipment down it. And you're probably going to need people to do something that fiddly.

Getting equipment to work on the Moon is a challenge we have yet to overcome. The lunar dust rises and falls with day and night because of electrical static charges. You can get dust flecks into your mechanisms that give you problems.

If you've got people there you can overcome

ABOVE: NASA's GRAIL mission flew twin spacecraft around the Moon to analyse its gravitational field, but not all Moon measurements can be taken from orbit

problems. They can deploy equipment and drill holes, and they can wander around making geological observations. The orange-coloured lunar soils were spotted by an astronaut from one of the later Apollo missions. They thought it was something rusty but it was orange beads from an explosive volcanic eruption. If you've got trained people there, they'll spot the unusual things.

The Mars rovers – impressive though they have been – haven't gone as far as astronauts driving the Moon buggies around. It's a lot more expensive when people are there, but you get a lot more done.

I was a kid when Apollo happened and I thought it was the future, I thought that was what we were going to be doing: people in space. It was inspiration for me. There is a benefit from just seeing people up there because it inspires the next generation of scientists. I don't think you can decouple that from the scientific facts that you are going to find out. As well as the mysteries that you are going to unravel, you're also going to be inspiring the next generation of scientists."



GONZALO MUNÉVAR

Philosopher, Lawrence Technological
University, Michigan

"Philosophy has to do with understanding our relationship with the world. In that sense, it is inextricably bound to science. It seems to me that the philosophical concern of this is what happens if we go to places like the Moon.

We can look at what has already happened. By going to the Moon, with Apollo and other missions, we have come to understand better what the Earth is like. So knowledge of the planetary system and of the cosmos gives us knowledge of the Earth. It is not just idle curiosity. It is something that in the long run affects us because it makes us understand our place in the Universe, and once we understand the Universe – and this is the point of practically all knowledge – we can then interact with that world better.

For us, understanding what the Earth is like is extremely important because the Earth has changed. To understand that, we need to know what kind of planet the Earth was when it formed and what kind of forces have acted upon it. One of the most important objects that we have to study is the Moon. By going to the Moon only a few times we accumulated an extraordinary amount of knowledge about what the Earth was like because the Earth and Moon apparently formed together.

Even if this is not the case, it is still important to find out how the Earth and the Moon came to be together like they are.

The Moon has a record of collisions with comets and asteroids [shown by the size and number of craters on its surface] that we do not have on Earth. The Moon knows so much.

To understand the Earth is to understand the Earth as a planet, which means to understand what planets are, how they formed, how they evolved and how they relate to the Sun and so on. The Moon is so close to us. So going back to it is going to help us improve our understanding of our place in the Universe.

Exploring with humans is a lot more expensive and dangerous than doing it with machines but in the long run we have to do it any way. It also provides other benefits because humans are much more flexible than robots anyway.

Steve Squires, the person in charge of the Mars rovers, once said that he was so pleased with everything a rover had done in the previous six months, but he said that an astronaut could have done it all in a single day.

It is great that we have those machines, but eventually we need to be out there. I also think it is good to have adventures as a species so that people can then dream about them and participate in them.

Going to the Moon the first time around was so exciting. Going back will give us the opportunity to go to other, more exciting places."

This now iconic photo was taken by Buzz Aldrin to assist with research into lunar soils






**COMMANDER
CHRIS HADFIELD**
Astronaut, first Canadian to walk in space

The real question is at what point does our technology advance enough that exploration becomes economically viable. What parts are okay to be done by sensors, and how do we determine when people should go? We can stick a weather station in Antarctica and it will tell us the air temperature and the windspeed. But that is such a tiny piece of the information that we need to know about Antarctica. Most of the data needs to be inquisitively pursued, and robots are terrible at doing that.

There is nothing magic about the 'space' in space exploration, but people have a very skewed view of taking exploration into the third dimension. But it's inaccurate to think like this, as there are so many historical cases that are almost identical. You could say, 'Oh well the technology is too expensive.' Well, it was pretty expensive to do each of those things at the beginning but then it becomes a part of what we do and who we are as a species.

So should we forsake lunar exploration for Martian exploration? They're both largely unknown. The real question is how do we not blow it. How do we not make fatal mistakes. We're going to get it wrong. On the [International] Space Station, on my three spaceflights, stuff went wrong all the time. You would have a hard time counting the number of times that we needed to be saved by bringing replacement equipment up from Earth.

If we go to Mars for a six-month voyage, then we are basically trapped in our own ignorance. We're going to end up being like the Franklin expedition, where you think you know what you're doing but you kill everybody. We have to recognise that failure is a big, big part of success, so you have to give yourself the opportunity to fail without destroying the entire effort that you are trying to accomplish." 

An Apollo 17 astronaut uses a moon buggy to explore the lunar surface



“EXPLORATION IS
FUNDAMENTAL TO
HUMAN NATURE.
IT IS WHY WE WALK
BEFORE WE TALK”



Chris Hadfield's videos and photos of his time aboard the ISS captured the imagination of millions of social media users around the world

PHOTO: NASA/ESA ILLUSTRATION: KATE COOPER/AND

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Do social networks make us antisocial?

MANY OF US HAVE EXPERIENCED THE WAYS IN WHICH SOCIAL MEDIA HAS CHANGED THE ONLINE WORLD. BUT SHOULD WE BE WORRIED ABOUT IT ALTERING OUR BEHAVIOUR TOO?

WORDS: DR DEAN BURNETT

Dean is a doctor of neuroscience at Cardiff University. His debut book, *The Idiot Brain*, is available now. You can follow him on Twitter @garwboy

R

ecently, I witnessed the unpleasant breakdown of a relationship. One partner accused the other of infidelity and promiscuity; the other retaliated with claims of emotional abuse, drunken behaviour and an inability to perform sexually. All this, in much more swearsy language than that conveyed here. It got nasty fast, with children being dragged into it, and friends taking sides and furiously rowing with those who'd taken the other side. All very grim, and it made me vow to avoid any and all of those involved as a result.

That wasn't difficult though, as I'd never actually met any of them to begin with. This whole breakdown happened on Facebook. Some friends of friends had asked to add me to their network, I'd unthinkingly agreed, and thus I ended up with a front-row seat to their hideous break-up. Ironic, that a social network was essentially responsible for the destruction of so many social bonds.

You've no doubt heard many complaints about social networks before. They're time-consuming, invasive, confusing, compromise your privacy and so on. But do they actually make us *antisocial*? Is there any credibility to that claim?

"The truth is, our social interactions, both online and in person, have a huge effect on our thinking and cognition"

If, like many do, you draw a clear line between online interactions and real-world interactions, with more importance being placed on the latter, then yes, arguably there is. But to really get to the heart of the matter, you have to look at how social networks affect our behaviour and actions towards other people. They can and do have significant impacts on these things, because of the way our brains work. The truth is, our social interactions, both online and in person, have a huge effect on our thinking and cognition. The social brain hypothesis, first put forward in

the 90s by anthropologist Robert Dunbar, suggests that our sociable nature is why we have such big brains to begin with. The argument is that primitive humans banded together in communities, and this cooperative approach proved very useful for our survival. But this lifestyle requires a lot of information to be processed; who do you trust? Who will help you? Who owes you favours? And so on. A substantial amount of detail needs to be available at a moment's notice. Basically, you need a lot of grey matter to maintain this. That's the theory, anyway (and there are others).

In support of this, brain imaging studies have shown a network of regions, including cortical midline structures and temporo-parietal junctions, which show increased activity when the subject contemplates being part of a group. Areas like the ventral medial prefrontal cortex and anterior cingulate cortex show increased activity when processing our sense of self, our identity, and when processing awareness of the groups or communities we feel we're part of. This all suggests our social interactions are a major component of our identity, at a very fundamental level.

SOCIAL BUTTERFLIES

Humans need social interactions. Depriving humans of social contact, as when prisoners are sent to solitary confinement, is recognised by psychologists as a form of torture. On the other hand, too much social interaction isn't good either. Social interaction is mentally taxing; engaging with someone is a lot of work for the brain, as it requires mental effort. This explains the apparent contradiction between humans needing social interaction, but also needing privacy. Social interaction wears our brain out, so we need privacy to get away for a bit and 'recharge'.

All this shows that the brain strikes a precise balance to ensure we get the most from our social interactions. But just as putting 10 times the required amount of sugar into a cake doesn't make it 10 times better, so social networks can amplify aspects of socialising and social relationships in ways that are unhelpful, if not downright harmful.

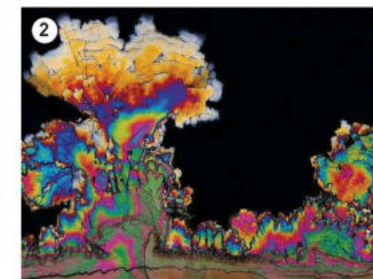
As early as 2010, professional psychiatrists were arguing that social network addiction was a real ●



1 Compared with other animals, including our closest relatives, we are quite friendly

2 Dopamine is released by the brain when we enjoy a successful social interaction, giving us a rush of pleasure

3 We can control how we portray ourselves online by only posting the best updates, videos and images



PHOTOS: SCIENCE PHOTO LIBRARY/GETTY X2



Social networking can trigger reward pathways in the brain, and may lead to addiction



We are social creatures – isolation is used as a form of torture and can warp the mind



Spending time socialising with people can be hard work for the brain

“As early as 2010, psychiatrists were arguing that social network addiction should be classed as a disorder”

phenomenon that should be classed as a clinical disorder, citing a case study of an individual who spent five hours a day checking Facebook, rarely leaving the house to do so, losing jobs and in one case interrupting the therapy consultation to check their updates – tantamount to opening a beer during an AA meeting. It essentially means cutting off all other forms of social contact to focus solely on social media, to the detriment of your overall existence.

There are explanations for this. A successful social interaction means we experience a real-world reward in the brain. Oxytocin release gives a general sense of well-being and connection, and the mesolimbic reward pathway, buried deep in the centre of the brain, releases dopamine, giving a rush of pleasure. Some argue – and a few studies even provide some evidence – that a successful social interaction online, such as a popular Facebook post or widely shared tweet, can also produce this positive response in the brain.

Unfortunately, these social ‘hits’ are a lot easier to get online, without all the effort of ‘normal’ social interactions. Drugs of abuse operate on similar principles, triggering the reward pathway, but without the hassle of actually doing the action that the brain would consider deserving of a

reward. Over time, the brain adapts to expect these pleasurable signals, and does things like disrupt the areas responsible for inhibitions or conscious self-control to keep them coming. Indeed, a 2013 neuroimaging study at the University of Zurich led by psychologist Dr Katrin Preller revealed that cocaine addicts have diminished activity in areas like the orbitofrontal cortex, resulting in reduced emotional empathy and willingness to socialise. So if social network addiction is exploiting similar mechanisms to cocaine addiction, then social networks may well be having an ironically negative impact on individual’s ability to socialise, rendering them more antisocial. More research is needed.

CONTROL FREAKS

Another issue is that people have a greater deal of control over their interactions online, meaning they can decide, to a much greater degree, how others experience them. You can put up only good photos, delete unwise comments, spellcheck, share smart memes and so on. This satisfies an underlying process the brain engages in known as ‘impression management’, where we’re constantly compelled to present the best possible image of ourselves to others, in order to make them more likely to approve of us.

A 2014 study led by the University of Sheffield’s Dr Tom Farrow looked at impression management. Using scanning technology, the team asked subjects to choose behaviours that would make people like them, and that would make people dislike them. Activation was recorded in regions including the medial prefrontal cortex, the midbrain and cerebellum, suggesting that these brain regions are involved in processing the image of ourselves we want to present to others.

However, these areas were only noticeably active when subjects tried to make themselves look bad – that is when they were choosing behaviours to make people dislike them. If they were choosing behaviours that made them look good, there was no detectable difference to normal brain activity. Coupled with the fact that subjects were much faster at processing behaviours that made them look good as opposed to bad, the conclusion was that presenting a positive image of ourselves to others is what the brain is doing all the time! It’s the brain’s default state.

Granted, it was a small and limited study, but it’s an interesting outcome nonetheless. And if we’re constantly focused on presenting a positive image of ourselves, it’s no wonder social networks are so popular, as they offer a much greater sense of control of how we come across.

But this control is a double-edged sword. Even if you’re just sitting with friends, the tendency to check your phone rather than talk can be overwhelming. The brain is usually averse to risk, preferring predictable options over less certain ones, and the cool, calm interface on the screen is often subconsciously more reassuring than the chaotic conversation going on around you. The people you’re with may consider this behaviour antisocial. And rightly so.

More worryingly, a 2015 survey of men aged 18-40 by Jesse Fox and Margaret Rooney in the journal *Personality And Individual Differences* revealed that the amount of time spent on social networking sites, posting selfies and, revealingly, editing selfies to make them look better, was correlated with traits like narcissism and psychopathy. This isn’t to say social networks cause these things, but they offer an outlet, a way for them to be expressed free of consequence,

where they may otherwise be criticised or challenged, thus ensuring more socially acceptable behaviours.

Another intriguing finding, from a 2015 study led by Prof Joy Peluchette at Lindenwood University, was that certain types of behaviour on social networks – namely extroversion and ‘openness’ – actually increase the odds of being a victim of cyberbullying. It may sound counterintuitive, but it makes a certain amount of sense. A person may typically keep their more flamboyant or expressive natures suppressed, because social norms deter such things. Subtle signs of discomfort in those around you, awkward body language and responses, muted atmospheres... these all act to keep gregarious or overly personal tendencies in check, to some extent.

However, such cues aren’t present online, so you can be as overly expressive or personal as you like on there. But other people may find this unsettling or off-putting, or could see it as cynical attention-seeking. Either way, they react aggressively, and attack the person. But social networks also protect the attacker from the consequences of their actions, introducing a distance and degree of anonymity between themselves and their victim, shielding them from the immediate effects, but supplying the same ‘rush’ of having lowered someone’s status and boosted their own. So social networks again become a way to facilitate and perpetuate antisocial actions.

Social networks also give us the ability to pick and choose what we see and hear from others, meaning we can end up in the oft-cited ‘echo chamber’. Social networks make it much easier to form groups, and constantly remain part of them. This can give us a more ‘extreme’ leanings, making more intolerant of contrasting views as we grow unused to encountering them. What should be a casual meet-up in a pub can easily become a blistering row about a football team. Antisocial behaviour, caused by social networks.

It’s not all doom and gloom. More nervous or socially awkward people can be liberated by the controlled and organised communication offered by social networks, and great friendships and relationships can form across the world now that would never have been able to exist before. But the truth is, for all that they may sometimes not work that well, the human brain has evolved a variety of systems to make sure social interaction happens as efficiently as possible. Social networks, though, throw many spanners in the works here, causing overall disruption, which can sometimes mean they end up achieving the opposite of what they’re built for, and making people antisocial.

Like and share this article if you agree!

DISCOVER MORE



Read a BBC iWonder article about why social media seems ‘fake’ to some people at bbc.in/2c8Grt

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ILLUSTRATION: JAMES OLSTEIN

GENETIC GOLDRUSH

Genetic testing is cheaper than ever. Companies are lining up to sell wine, shoes, fitness plans and more – all tailored to your DNA. But just how feasible are their claims?

Words: Kat Arney

In less than two decades, the science of human genomics – studying the genetic makeup of individuals and populations – has changed beyond recognition. The first full human genome sequence took 10 years and cost nearly \$3bn to deliver (at 1991 prices). Today you can spit in a tube, pop it in the post, and expect an email to arrive within weeks detailing thousands of variations within your DNA linked to traits, health and heritage, at a fraction of the cost.

Unsurprisingly, enterprising companies have been quick to jump on the genomic bandwagon, offering everything from fitness plans to personalised wine choices based on your genes. But is it really possible to get such detailed information from a glob of your saliva?

DIRECT TO YOUR DOOR

The story of direct-to-consumer (DTC) genetic testing really starts in the early

2000s. At this time, relatively little was known about how small differences in DNA sequences between people – known as single nucleotide polymorphisms, or SNPs (pronounced ‘snips’) – mapped on to disease risk or physical traits such as height, weight or taste preferences.

Nonetheless, companies sprang up offering pricey nutritional advice and supplements based on testing a handful of SNPs. Given the lack of solid scientific evidence linking SNPs to characteristics, these were dismissed by the authorities as being medically unproven and ambiguous.

By the middle of the decade, the gene-testers had started to wise up. Rather than purporting to offer any kind of medical advice or diagnosis, which would lead them to fall foul of regulators such as the US Food and Drug Administration (FDA), they now claimed to provide their SNP tests purely for informational and educational use. By 2009, more than 500 SNPs had been reliably linked to the risk of diseases such as cancer, and this ●

was growing year-on-year. Anyone with a burning biological curiosity and a thousand dollars to spare could now sign up to 'get their genomes done'. Yet despite their growing popularity, when experts analysed the results of these tests they found them to be misleading or even just plain wrong, driven by deceptive marketing rather than sound science.

Put off by regulatory crackdowns and a limited consumer base, many of the original SNP-based personalised genetics firms closed down or sold out to larger firms. But there have been a few survivors, and these companies continue to link SNPs to a wide range of disease risks, physical traits and ancestry. And as the pace of technology has accelerated and costs have plummeted, the genetic marketplace is opening up once again.

FAMILY TIES

One of the big boom areas is in genetic ancestry services, with companies offering to find your long-lost genetic relatives and trace your roots around the globe. Some of them even tell romantic stories of ancient tribes, fierce barbarians or sophisticated

"THERE'S VERY LITTLE HARD EVIDENCE THAT A GENETICALLY-TAILORED DIET IS ANY MORE EFFECTIVE THAN A GENERIC ONE"

BELOW: A printed copy of the human genome fills a whole book

RIGHT: A chip containing DNA is loaded into a machine for analysis

artists lurking up the ancestral family tree.

It's certainly possible to pin genetic heritage to certain parts of the world, particularly for populations rather than individuals (though even then it's a relatively imprecise science), as well as figuring out what percentage of your genome came from Neanderthals. But many scientists working in the field of human genetics and evolution are less convinced. For example, researchers from the Molecular and Cultural Evolution Laboratory at University College London have investigated and

debunked the more dubious claims as little more than "genetic astrology". They argue that the complex patterns of human mating and migration make it tricky to tease apart the tangled genetic threads in each of us with any degree of accuracy.

The other hot topic in DTC testing comes under the broad banner of 'lifestyle'. Companies now offer the chance to 'hack your body' and 'boost your human potential' with all kinds of dietary and fitness advice tailored to your personal combination of certain SNPs. Some recommend combinations of 'genetically selected' vitamins and dietary supplements, while others even offer personalised meals delivered direct to your door. But although these tests all claim to be supported by science – and while it's true that the SNPs they test for have been linked to weight, metabolism or other physical traits in large studies – there's actually not very much hard evidence available to suggest that following a genetically-tailored diet and fitness plan is more effective than following a generic one.

In fact, a large randomised controlled trial carried out by scientists at University College London and published in 2015 showed that giving people a weight loss programme alongside information about their personal version of a gene called FTO – which is associated with body weight – made them more likely to think about losing weight, but wasn't any more effective than the programme alone.

Another study showed no change in behaviour, at least in the short term, for people who were given genetic information about their risk of type 2 diabetes – although on the plus side, there was no increase in worry or anxiety either.

"My feeling is that [DTC tests use] quite a clever marketing strategy," says Dr Caroline Wright, programme manager for the UK's Deciphering Developmental Disorders study and scientific lead at Genomics England. "I think the science behind some of these things is going to be tenuous. There are research papers that link variations in DNA with certain attributes, but it doesn't necessarily mean that if you test that particular variant in a particular person it will be predictive for what they like or what they can do."



MORE DATA, MORE PROBLEMS

Taking advantage of the ever-shrinking cost of DNA sequencing, DTC companies are now moving on from SNPs and taking a deeper look at the human genome. The next step is exome sequencing – reading the entire genetic recipe of all 20,000 genes in the genome, without the misleadingly named 'junk' DNA that lies in-between.

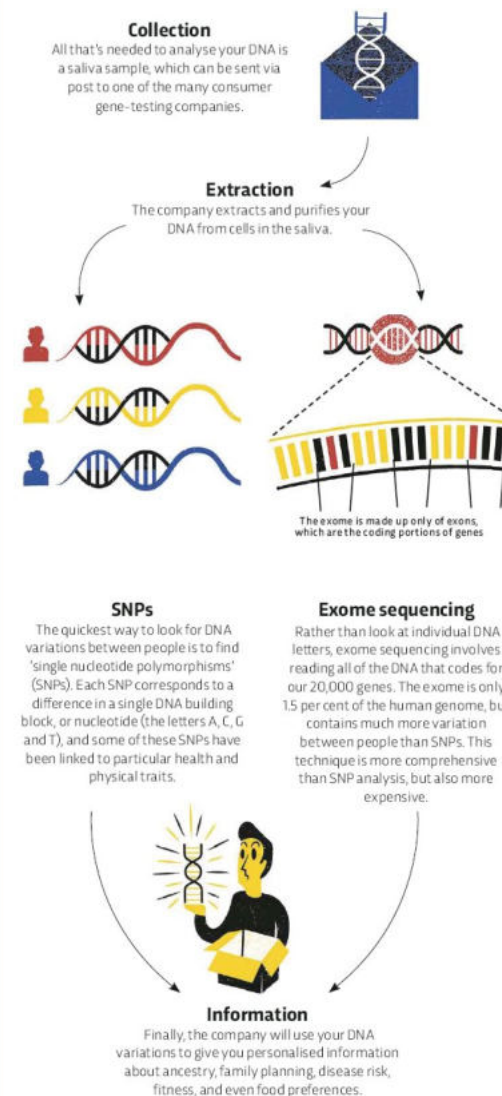
The first firm into the exome marketplace is Helix, backed by DNA technology giant Illumina. Based on the principle of 'sequence once, query often', Helix plans to store customers' exome data and allow them to access it through an app store, with third-party partners offering gene-matched products ranging from health analysis to lifestyle advice.

The first product on offer is Geno 2.0, which is an ancestry analysis package that's produced in association with National Geographic. Further partners are in the process of signing up, including a range of academic institutions such as Duke University and the Mayo Clinic. On the less serious side is Vinome, which offers customers regular deliveries of genetically-matched fine wines with "a little science and a lot of fun".

Whether Helix's exome-and-app approach offers anything more than the SNP-based ancestry or diet and wellness tests remains to be seen. The thornier issue will come if Helix offers analysis of genes involved in disease. Not only does this skirt the line with regulatory agencies such as the FDA, which demands that medical tests are only available

MINING THE GENOME

Personalised genetics companies use two main techniques to quickly and cheaply analyse your DNA. Here's how they compare...



THE GENETIC APP STORE

Direct-to-consumer gene-testing companies cover many areas of life. However, the scientific evidence supporting their products may be weak, so buyer beware!



DIET

Some companies are offering personalised diet advice based on a number of genetic markers – a field known as ‘nutrigenetics’. The idea is that matching foods to variations in genes that have been linked to obesity, fat metabolism and hunger will bring better weight control. And as a treat, you can buy bespoke beer or fine wines matched to your genes.



SPORT AND FITNESS

As well as matching your diet to your genes, you can tailor your workout, too. From weekend warriors to serious sportspeople, companies offer to analyse genes involved in aerobic (oxygen) capacity, power, endurance, blood pressure and even tendon strength to suggest an ideal training programme, along with a rest and recovery plan.



LOVE AND FAMILY

You can now look for a ‘DNA compatible’ partner, based on comparing a group of genes involved in the immune system known as the major histocompatibility complex (MHC). Parents can be tested to see if they’re likely to produce a child with a genetic condition. And once baby arrives, it’s even possible to order a genome test to see what character traits or health risks it’s inherited.



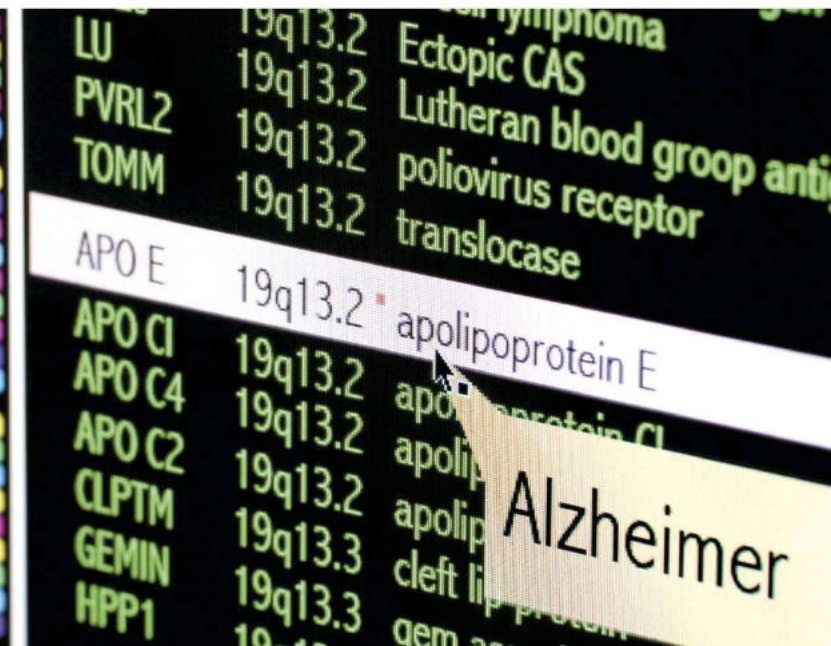
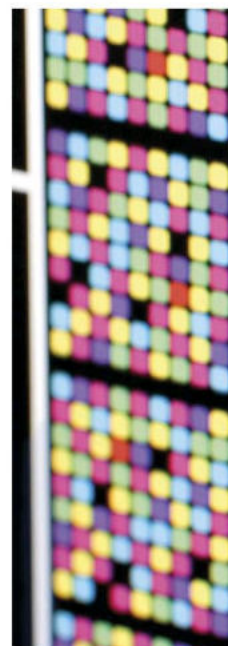
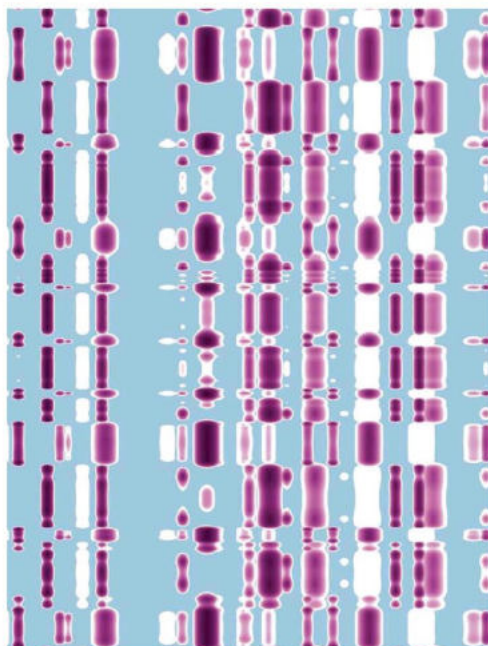
SKINCARE

Skincare companies are now offering DNA-based solutions that claim to turn a grotty face into a glowing one. By looking at genes involved in antioxidant protection – which prevents damage from UV rays and chemicals – and the breakdown of the collagen fibres that maintain skin’s plumpness, scientists create a personalised anti-ageing serum.



PETS

There’s no reason why your pet can’t get their genes tested, too! You can now prove whether your pup is pure-breed, or untangle the parentage of a mysterious mutt, as well as looking for health-related DNA variations. Like human DTC tests, you can even get ‘wellness advice’ about diet, fitness and veterinary care tailor-made for your pet.



ABOVE LEFT: An autoradiogram showing the order of nucleotide bases in a sample of DNA


ABOVE: A DNA sequence reveals the presence of APO E, a genetic marker for Alzheimer's

But with the cost of sequencing falling rapidly, it might only be a matter of time – especially as Illumina's new NovaSeq machine promises to bring the \$100 genome within range. Yet for all the excitement and talk of high-tech apps fuelling the consumer genomic revolution, the same issues remain that have always dogged genetic testing, particularly around privacy, consent and the question of who gets access to the data.

Yet for all the excitement and talk of high-tech apps fuelling the consumer genomic revolution, the same issues that have always dogged genetic testing remain, particularly around privacy, consent and the question of who gets access to the data. Whiling away some idle time in a genetic app store is likely to be a harmless curiosity for most people, and at a time when it's important to encourage the public to engage with genetics, it seems churlish to raise a note of caution. But wringing data out of your genome could raise more questions than it answers.

“THE SAME ISSUES THAT HAVE ALWAYS DOGGED GENETIC TESTING REMAIN, PARTICULARLY AROUND PRIVACY AND CONSENT”

“Information about ancestry, fitness and what kind of wine you like might also be mixed in with whether you've got high susceptibility to breast cancer or a gene variant that means you're going to get Alzheimer's disease early in life,” says Wright. “Those are quite different types of information, but you'll be able to get it all from your genome. Some of them are fun, and some of them really aren't.”

We're seeing the start of a genomic gold rush: in a few years, having your DNA sequenced and rifling through it could be as simple and fun as browsing TV box sets. But it's important to remember that these companies hook curious consumers with promises of genetic insights because they want to make money. This is powerful, personal information, with potentially life-changing consequences, and it's worth handling with care. 

Kat Arney is a science writer and broadcaster. Her first book, *Herdin Hemingway's Cats: Understanding How Our Genes Work*, is out now.



×
: Jeff Forshaw and Brian Cox :
GUIDE TO THE COSMOS



Part I of IV

THE UNIVERSAL FABRIC

To understand the cosmos, we first need to get to grips with the nature of space and time. And when we start to do that, some strange ideas emerge...

About this series

In this exclusive four-part series, physicists Jeff Forshaw and Brian Cox introduce us to the biggest ideas in modern physics and cosmology. What is the nature of time? What is everything made from? What happened before the Big Bang, and how will the Universe end? We'll delve into the deepest questions concerning the very essence of space, time, matter, and reality itself...

Here's a strange idea: it is impossible to catch up with a beam of light. Light travels at 300 million metres every second, but if you chased after it at 299 million m/s, it would still be receding from you at 300 million m/s, not at the 1 million m/s you might expect (strictly speaking, the light should be travelling through empty space). That crazy-sounding idea comes from Albert Einstein, and is the bedrock of his Special Theory of Relativity. ●

**CBBC
TWO**

From 28-30 March, Brian Cox presents *Stargazing Live* with Dara O Briain, bringing you the best of the cosmos live from Australia. Turn to p88 for more details.

ILLUSTRATIONS: SAM CHIVERS, KATE COPELAND





“Time does not tick at a steady rate across the Universe – in some places it ticks faster”

✦ The implications of Einstein's idea are enormous. For example, it means that time does not tick at a steady rate across the Universe – in some places it ticks faster than in others, and it becomes possible for people to age at different rates depending on where they are and what they are doing.

Perhaps the most dramatic example of this is the ‘twin paradox’, where an astronaut departs from Earth, leaving her twin brother behind. She zips around for a bit in her super-fast spaceship and then lands back on Earth a year later, only to find that many more years have passed back home, and her brother is now an old man. This is exactly the kind of weirdness that must be true if Einstein is right – though we aren't aware of it in our everyday lives because we can't

zip around fast enough, and so are tricked into thinking time is more constant than it actually is.

The fact that a moving clock does not tick as fast as a stationary one is actually quite easy to demonstrate. First, imagine a clock made from two parallel mirrors, between which a particle of light or ‘photon’ bounces back and forth (see ‘The key idea’, right). Imagine you have one of these little clocks in your hand, and that you can watch the particle as it goes up and down, counting the bounces as a way of measuring time. Now imagine that a friend also has one of these clocks, but that she's moving horizontally.

From your point of view, her photon traces out two sides of a triangle as it bounces from one mirror to the other and back again, travelling further during each round trip than the photon in your clock.

There's nothing controversial in what we just said. Here comes the weird bit. Because, according to Einstein, the light bouncing in your friend's clock is travelling at the same speed as the light in your clock, the light in your friend's clock must take longer to bounce between the mirrors. In other words, your friend's clock is running slower than yours.

This remarkable conclusion might sound like a special feature of light clocks. But it isn't... it is a feature of *all* clocks. To understand why, we need to introduce Einstein's second crucial idea – an idea first introduced by Galileo Galilei in the early 1600s.

IT'S ALL RELATIVE

Galileo imagined a ship moving at fixed speed over a calm ocean. Inside this ship, below decks, is a host of “flies, butterflies and other small flying animals”. He noted that, from observations of the creatures made only inside the ship, it would be impossible to tell whether the ship was moving or standing still. The idea that experiments and observations made in a laboratory ‘at rest’ give exactly the same results as those made in a laboratory that's moving uniformly is called the ‘principle of relativity’, and Einstein followed Galileo in assuming it to be true. According to this principle, if a moving light clock is ✦

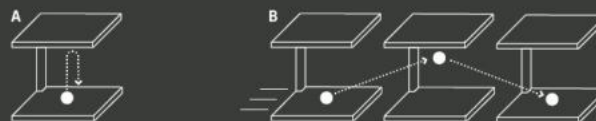
PHOTO: GETTY. ILLUSTRATION: SAM CHIVERS



The key idea

MOTION SLOWS THE PASSAGE OF TIME

Imagine a clock made from two parallel mirrors with a photon (particle of light) bouncing between them. If the mirrors are placed the correct distance apart, the photon will take one second to make a round trip between them (A). If the clock is moving horizontally, however, the photon will trace out two sides of a triangle, travelling a greater distance (B). Since the speed of light is constant, the photon will take longer to bounce between the moving mirrors, and – from our point of view – each second on the moving clock will take longer than on the stationary clock.



The Andromeda galaxy – 50 years away (if you could travel at 99.9999999 per cent of the speed of light)

Glossary

LIGHT CLOCK

A type of clock where light bounces between a pair of mirrors. These provide a useful way to think about Einstein's Special Theory of Relativity, which says a moving clock will run slower than a stationary one.

TWIN PARADOX

The puzzle that two identical twins should age at different rates depending on how they move. There's actually no paradox – Einstein's Special Theory of Relativity explains why this is true.

NEUTRON STAR

These astonishingly dense dead stars have a mass roughly equal to the Sun, but squeezed into the size of a city. Spinning neutron stars emit pulses of radio waves, which can be used by astronomers to test Einstein's theory of gravity.

PRINCIPLE OF RELATIVITY

The idea that there is no way to define ‘at rest’ in any absolute sense. In other words, all motion is relative.

SPACE-TIME

Modern physics combines the three dimensions of space and the one dimension of time into this single, four-dimensional entity.

GRAVITATIONAL WAVE

A moving ripple in the fabric of space-time that causes lengths to change and clocks to tick at different rates as it passes by.

● slowed down, then so must all other moving clocks be, including our wristwatches and our heartbeats. To appreciate this point, let's suppose light clocks *are* actually special, and that they slow down while other types of clock do not. If this were true, a person could compare their light clock with their wristwatch and, because the light clock would be running slow, they would know that they were moving. Since this contradicts the principle of relativity, logic tells us that light clocks cannot be special.

The principle of relativity also means that movement is always relative. It makes no sense to say "I am moving when I cycle down the road" – it only makes sense to say "I am moving relative to the road". This isn't as boring an observation as it sounds. A moving clock runs slow compared to one at rest, but it would be equally valid to regard the moving clock as being 'at rest' and the other clock as moving. In which case we appear to be saying that each clock runs slow compared to the other, and that sounds like nonsense. But remarkably, there is no logical contradiction here. For example, it is okay for person A to say that person B is ageing more slowly and for person B to say that it's person A who is ageing more slowly; these two statements are

both true so long as A and B are in uniform motion *relative* to each other. Of course, A and B cannot both be younger than each other if they actually meet up for a cup of coffee. But in order to do that, one or both must accelerate or decelerate, and then the two of them will no longer be moving relative to each other.

We can use this logic to shed a bit more light on why the astronaut twin really does age less than her Earth-



"This is a lovely result because it implies that humans can conceivably explore the cosmos"

bound brother. From the point of view of her brother, she is always ageing more slowly than he is because she is always moving relative to him, and because he never accelerates or decelerates (he is 'in a state of uniform motion'). This means his sister must be younger than he is when she returns.

Understanding this from *her* point of view is more tricky. Actually, her brother is ageing more slowly than she is during those parts of her journey where she is moving uniformly. It is only when she is accelerating or decelerating (which she needs to do in order to return to Earth) that her brother suddenly ages and this is why, when she finally returns, he is older.

FLIGHTS OF FANCY

Andromeda is our neighbour. It is a spiral galaxy containing one trillion stars, and is situated around 2.5 million light-years from Earth. This means that light arriving in our telescopes today started its journey from Andromeda before there were any humans on Earth. It also means that a space expedition travelling at the speed of light would take at least 2.5 million years to reach the galaxy, *as determined using clocks at rest relative to the Earth*. Such a long journey seems to imply that no human could ever travel to Andromeda. But that is not true, and those italicised words are the key.

Just as with the twin paradox, the astronauts onboard the spaceship will age much more slowly than the folks back on Earth, and the faster the spaceship travels, the more this will be the case. In fact, we can work out that a spaceship travelling at 99.99999999 per cent of the speed of light could travel to Andromeda in just 50 years as measured by those on board the spaceship (and 2.5 million years as measured by people on Earth). This is a lovely result because it implies that humans can conceivably explore the cosmos. We are not forever trapped within the confines of the Milky Way – we just have to invent a spacecraft that will transport us fast enough.

Putting dreams aside, the feasibility of a 50-year-long journey to Andromeda highlights another intriguing conundrum, which again calls into question the nature of ●



ABOVE: Jodrell Bank's Lovell Telescope played a part in confirming the existence of gravitational waves, and so confirming Einstein's theories

Relativity in five steps



1.

The speed of light as it moves through empty space is the same for everyone, which means it would be impossible to catch up with a beam of light, no matter how fast you might, hypothetically, be travelling.



2.

It's also impossible to tell the difference between moving uniformly and not moving at all – this is known as the principle of relativity. Einstein's principle was pre-empted by Galileo in the 17th Century.



3.

From these two ideas, Einstein concluded that time and distance are not constants: moving clocks run slow, moving rulers shrink. So someone zipping around in a spaceship will age slower than someone on Earth.



4.

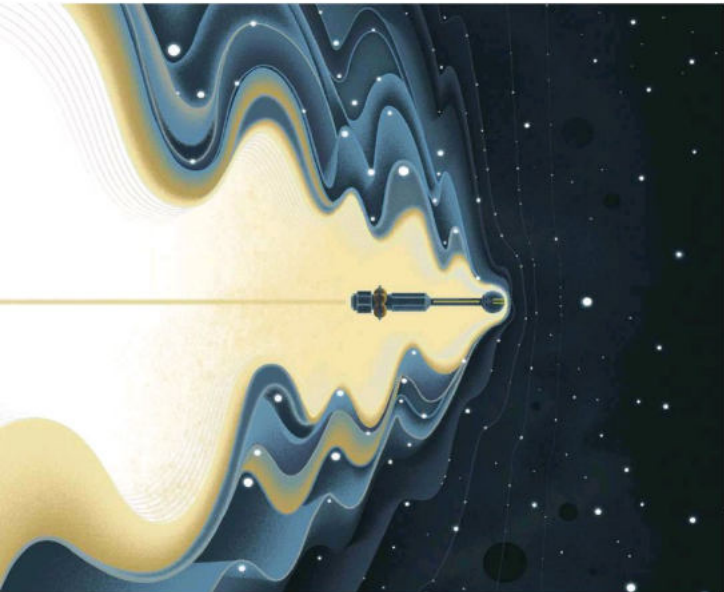
Gravity also affects the passage of time. Clocks slow down under the influence of gravity so, for example, clocks tick faster at the top of Mount Everest. This is a key result of Einstein's General Theory of Relativity.



5.

Space and time are not fixed – they are malleable and subjective, and together they form a universal, four-dimensional fabric called space-time. This idea is central to physics.

PHOTO: GETTY. ILLUSTRATIONS: SAM CHIVERS





● space and time. Let's think about the journey from the perspective of those onboard. For them, Andromeda is hurtling closer at nearly the speed of light. If the spaceship had to travel 2.5 million light-years, then it would take 2.5 million years to get there. But as we've just seen, it will arrive in 50 years. This implies that, from the spacefarers' point of view, the distance to Andromeda is just 50 light-years.

In other words, Einstein's theory forces us to conclude that, like time, distances in space are also subjective things. It simply does not make sense to say that "the distance to Andromeda is 2.5 million light-years." We have to add the caveat, "as determined by people on Earth."

WHAT GOES UP...

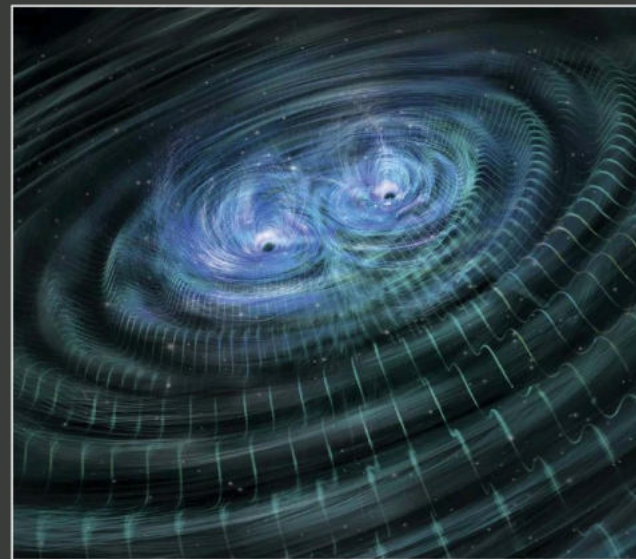
Einstein wrote down his Special Theory of Relativity in 1905, his *annus mirabilis*. But there was more to come. In 1915, he came up with a new theory of gravity, which superseded the one written down more than 200 years earlier by Isaac Newton. With his General Theory of Relativity, Einstein

✕
"Einstein made the bold claim that a clock placed at sea level ticks more slowly than one placed at the top of a mountain"

made the bold claim that a clock placed at sea level ticks more slowly than one placed at the top of a mountain. In other words, time passes at different rates depending on the strength of gravity (which decreases as you get further from Earth's core).

We can appreciate why this might be true by calling, once again, upon the wisdom of Galileo. As legend has it, he dropped a heavy ball and a light ball from the Leaning Tower of Pisa, and confirmed that the two hit the ground at the same time. He had shown that all objects accelerate to the ground at the same rate. This feature of gravity is intriguing because it means there's no difference between doing an experiment on the Earth and doing it inside a spaceship accelerating at 1g (which is equal to the gravitational pull at the Earth's surface). In other words, the effects of gravity and acceleration are essentially the same.

So how does this link in with Einstein's ideas about gravity? Let's return again to the twin paradox. When the astronaut twin fires up her rockets and accelerates her spaceship,



ABOVE: Gravitational waves – ripples in the fabric of space and time – confirm Einstein's theory

✕
"Einstein's theory forces us to conclude that, like time, distances in space are also subjective"

her experience is the same as someone who is under the influence of a gravitational pull. Since, as we've already shown, her time runs more slowly than her brother's during this part of her journey, and since her experience is identical to that of someone experiencing gravity, we can conclude that time runs slower for clocks that are under the influence of stronger gravity.

Today, Einstein's ideas have been tested to exquisite precision. Some of the best evidence comes from studies of a pair of rapidly spinning neutron stars and, more recently, from observations of the merging of a pair of black holes. As the pair of neutron stars, or black holes, orbit around each other, Einstein's theory predicts that they should cause ripples in the four-dimensional fabric of space and time (or 'space-time'), which propagate outwards like ripples on a pond.

In the case of neutron stars, the emission of these 'gravitational waves' causes the stars to spiral slowly inward. Astronomers, including those at Jodrell Bank in the UK, have used

radio waves emitted by these stars to calculate that they spiral inward at a mere seven millimetres each day. With black holes, the spiralling is more dramatic: they collide, and the predicted ripples in space-time have been directly measured as they pass by our planet. On a more down-to-Earth level, the entire GPS network would fail within hours if the onboard clocks were not adjusted to account for the fact that moving clocks run slow, and that clocks in the weaker gravity of high-Earth orbit run fast (these are opposite effects, but they don't precisely cancel out).

Albert Einstein taught us to ditch our prejudice that space and time are fixed and inert things. Instead, we need to see them as malleable and subjective. Together they form a shape-shifting, universal fabric on which the entire cosmos plays out.

Understanding the nature of space and time is one of the two pillars of modern physics. In next month's article we will meet the second pillar: quantum theory. Things are about to get even weirder... ●

Jeff Forshaw is professor of particle physics at the University of Manchester. He has co-authored three popular science books with Brian Cox.

Brian Cox is professor of particle physics at the University of Manchester and the Royal Society professor for public engagement in science. His BBC TV and radio work includes *Wonders Of The Universe*, *Forces Of Nature*, *Stargazing Live* and *The Infinite Monkey Cage*.

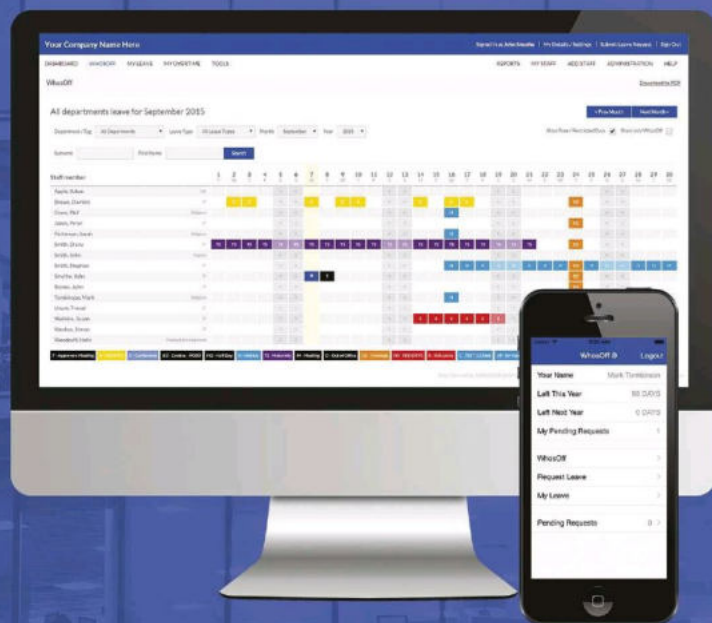
DISCOVER MORE

■ Einstein's theories are covered in more depth in Brian and Jeff's first book, *Why Does $E=mc^2$?* (£8.99, Da Capo).

■ Brian and Jeff's latest book is *Universal: A Guide To The Cosmos* (£25, Allen Lane).

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HELEN CZERSKI... **DECIPHERING HAIR CARE**

"THE SHIMMER OF A SUNSET OFF THE OCEAN MIGHT JUST HAVE SOMETHING TO SAY ABOUT YOUR HAIR"

Pouting down at me from a poster on the wall was a glamorous model, crowned with a shining fountain of impossible hair. A selection of different hairbrushes located to my left were laid out like a toolkit, primed for the pursuit of perfection. My own wayward mane kept falling into my eyes, betraying my utter ambivalence towards the hair care trade. But the hair scientist that we had come to visit was determined to extract my opinion anyway. He was gesturing at three shiny tresses of hair, perfectly combed and displayed under a bright light. He was asking a question: "Which one of these do you think is in the best condition?". I was clearly about to fail the first test of hair care, because all of the tresses looked exactly the same to me. And then, just before I admitted my ignorance, my brain made the link with the ocean.

The mighty Pacific Ocean was my companion when I made the switch from my PhD topic to oceanography, and was introduced to the mysteries of our planet's oceans. At the Scripps Institution of Oceanography in California, where I was based, the Pacific was the backdrop to everything. Every Friday after work, the scientists would gather at a wooden hut on a cliff, watch the sunset over the ocean and drink beer. It was there that I first noticed the sparkly line on the water's surface when the Sun was low, reaching out directly towards me. It's poetically known as a 'glitter path', as sunlight sparkles off the ocean into your eyes. And on this very same cliff top, decades earlier, two physicists had worked out that the glitter path carried information.

You can often see a glitter path on rivers and lakes as well as the ocean, whenever the Sun is low in the



sky. And they vary in width. Sometimes you see a wide line close to the Sun, which becomes narrower as it comes in towards the shore. And sometimes it bulges in the middle, or near the coast. The water isn't a perfect mirror, because it isn't completely flat. If it was, then you would just see an upside-down image of the Sun reflected in its surface. But that's rare. A glitter path is made up of thousands of individual sparkles, as different waves catch the Sun's image. Those waves can be slightly off to the side, or in front of, or behind the perfect image, and you see the sparkles as different waves catch the light coming from the Sun and redirect it to you. So the rougher the water is, the wider and longer the glitter path, because there are lots of different places that a wave can be and still bounce sunlight towards you. A narrow glitter path tells you there's calmer water. Even though you can't see the individual waves – they're relatively small and they could be miles away – the glitter pattern is providing a

measure of surface roughness.

And so back to the hair. An individual strand of hair is covered with tiny scales. On healthy hair, the scales lie down flat, but on damaged hair, they stick out at all sorts of funny angles. One of the hair tresses was reflecting the bright light in a really narrow line, and the others were wider. The same principle was at work both here and on the ocean – I couldn't see the scruffed-up scales on the damaged hair, but I could infer their existence from the shine pattern. I pointed at the one with the narrow shine pattern, and the hair scientist beamed at me. Maybe there's hope for me yet in the world of hair care. 

Dr Helen Czerski is a physicist and BBC science presenter. Her book, *The Storm In A Teacup*, is out now (£8.99, Transworld).

NEXT ISSUE: WHY DOES SPINACH GO DARKER GREEN WHEN COOKED?

Dr Saunders strikes back

Psychiatrist suffers stroke, then analyses symptoms to help others

Dr Tony Saunders always looked after his health, so it seemed doubly unfair when he collapsed with a major stroke in the gym.

Tony's family were worried that he could die, as stroke takes a life every 13 minutes in the UK. And it's the leading cause of severe adult disability.

Fortunately, with excellent treatment, Tony eventually returned to work.

But Tony noticed that discussing his stroke made him anxious – he even started stuttering.

As a psychiatrist, he identified this as post-traumatic stress disorder. He then realised that, on top of his medical training, he now had valuable first-hand experience of stroke.

So Tony struck back by overcoming his anxiety, and giving talks to medical students. As a result,

a new generation of doctors are supporting their patients with powerful new techniques.

This is Tony's legacy. And now you can strike back against stroke too, by leaving us a legacy of your own.

Stroke
association

Together we can conquer stroke.

Call 020 7566 1505 email legacy@stroke.org.uk or visit stroke.org.uk/legacy

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YOUR QUESTIONS ANSWERED

APRIL 2017

EDITED BY EMMA BAYLEY



Do elephants really never forget?

THEO HUNTER (AGED 11), SHEFFIELD

An elephant has a very large brain for its size and the 'temporal lobe' region responsible for memory is more developed with a greater number of folds – this results in powerful abilities to 'download' important survival data such as where to find food and water, and who is friend or foe. The matriarch of a herd (who can live for 60 years) may recognise over 200 individual elephants and can react to the call of a deceased member of her herd two years after their death. During droughts, these grandma elephants lead family members to waterholes by recalling detailed maps they've made spanning hundreds of kilometres. So although they undoubtedly forget what they don't need to remember, they appear to remember what they cannot afford to forget! **ec**



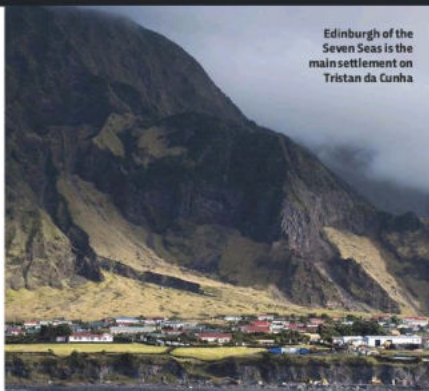
From left to right: preserved penis bone of domestic dog, coatiimundi, kinkajou and red fox

Why don't humans have a penis bone?

CLAIRE RUSSELL, LEICESTER

The penis bone or 'baculum' is common to lots of placental mammals but by no means all of them. It seems to have evolved independently nine times in different mammal lineages but it has also subsequently been lost in many cases. Among primates, humans are the only ones without a baculum, although it is tiny in gorillas and chimpanzees.

The baculum allows prolonged penetration and it is normally only present in animals that mate for longer than three minutes. Lengthy sex sessions are an adaptation to maximise the male's chance of impregnating the female. Humans evolved monogamy as a reproductive strategy, which – along with other social rules – reduces the risk of females mating with rival males. Men can therefore get away with shorter copulation times. **LV**



Edinburgh of the Seven Seas is the main settlement on Tristan da Cunha

What's the most remote inhabited place on Earth?

JESSIE BAKER, CARDIFF

That record normally goes to the Tristan da Cunha islands in the South Atlantic, which are 2,434km from Saint Helena. But they are only the most remote if you consider Tristan da Cunha Island itself and Gough Island as part of the same archipelago. The two islands are both inhabited and only 399km apart from each other. Discounting these, the next most remote is Easter Island, which is 2,075km from the nearest other inhabited spot, Pitcairn Island. **LV**

IN NUMBERS

30

The percentage of doctor visits relating to complaints of being tired all the time, according to a study by Dutch scientists.

3

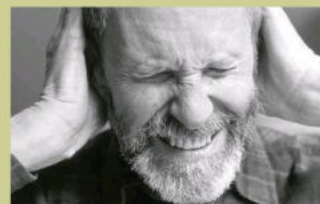
The number of pups born to a zebra shark called Leonie, despite being separated from her mate for four years.

36

The number of unique types of offshoot there are in the Peruvian rainforest, according to new research that mapped chemical signatures in the tree canopy.

Why do our ears ring after we listen to loud music?

MEREDITH BAILEY, HORSHAM



Loud sounds can damage the hair cells in your cochlea of your inner ear. This causes some degree of hearing loss and your brain tries to compensate by turning up the gain control so the signals from remaining healthy hair cells are amplified. This also amplifies random noise in the signal, which we hear as a ringing. Prolonged or repeated exposure to loud noises can damage or kill the hair cells for good. **LV**

What's the slowest a plane can fly?

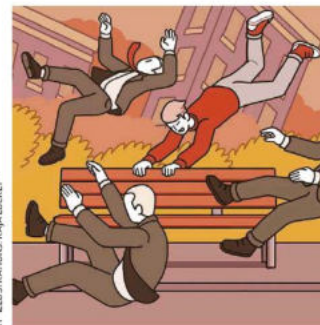
LUCIE COLTMAN, LOUGHBOROUGH

Technically this is the so-called 'stall speed', where air passes over the wings fast enough to sustain altitude, and for small planes this can be less than 50km/h (31mph). But at such low speeds, the aircraft is easily destabilised, and could fail to leave the runway. So for safety and stability at take-off, commercial airliners must achieve substantially higher speeds exceeding around 250km/h (155mph). **RM**



THE THOUGHT EXPERIMENT

WHAT WOULD HAPPEN IF THE EARTH STOPPED SPINNING?



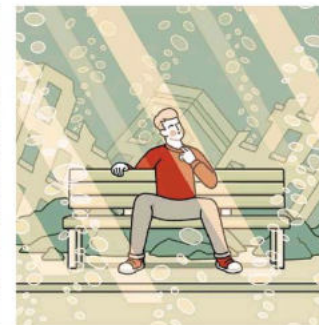
1. SUDDEN STOP

If the planet stopped suddenly, everything on the surface would be destroyed, as the atmosphere, oceans and anything not nailed down kept spinning. Even braking to a halt over a minute would mean everything experienced a sideways deceleration of three-quarters of Earth's gravity, so 'down' would feel like it was at an angle of 38° from the vertical. That's enough to knock over most buildings.



2. CHANGING CONTINENTS

If it slowed down over several years, it would still be a disaster. Without centrifugal force, the oceans would move towards the poles, dropping ocean depth by 8km around the equator. Since this is less than the depth of the ocean there, Earth's water would be divided into two huge polar oceans separated by a belt of land in the middle. Everything north of Spain would be underwater, as well as all of Antarctica.



3. BAKE AND FREEZE

Once Earth doesn't spin on its own axis, a day lasts as long as a year. Everywhere receives six months of daylight, gradually heating up the planet to well over 100°C. The huge central continent would get the hottest and any remaining lakes and rivers would boil away and be blown to the poles by fierce winds. Even primitive life would only be possible along a narrow strip at the coast.

Why is Jupiter stripy?

OLIVER FLIPPANCE, KENILWORTH

Jupiter's stripes or 'bands' are caused by differences in the chemical composition and temperature of the atmospheric gas. The light-coloured bands are called 'zones' and show regions where the gas is rising. The dark-coloured bands are called 'belts' and show where gas is sinking. It used to be thought that the only cause for these bands was the strong atmospheric winds coupled with strong convection cells circulating material between different layers of the atmosphere. However, it is now thought that Jupiter's moons also play an important role in making Jupiter stripy by tugging on the planet's atmospheric convection cells. **AGu**



IN NUMBERS

54

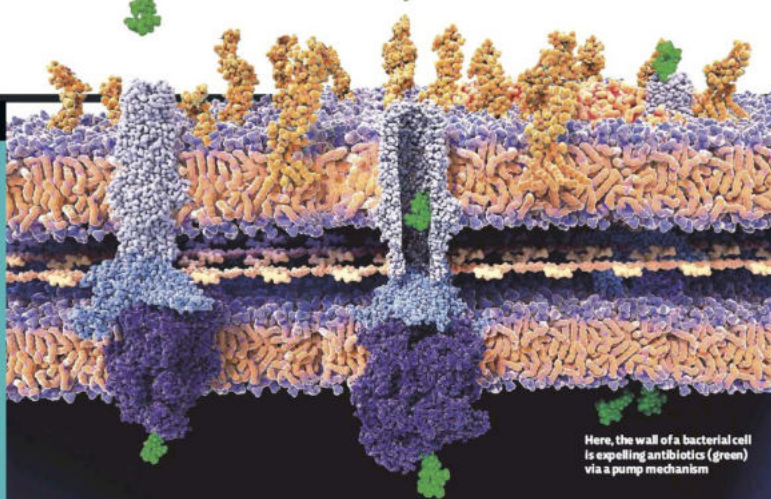
The number of days that traces of the Zika virus can linger in the blood, after symptoms have appeared.

35

The percentage increase in efficiency of wind turbines, when their design is inspired by insect wings.

30

The number of vaquitas left. Conservationists want to capture some of the remaining individuals of this small porpoise species for captive breeding.



What causes antibiotic resistance?

EDDIE FRIEL, HULL

Antibiotic resistance is a good example of natural selection. Exposure to antibiotics increases selective pressure in bacterial populations, boosting the percentage of resistant bacteria, with new bacterial generations inheriting resistance genes. Bacteria can sometimes pass on resistance by sharing genetic material with each other. They can also become resistant following

spontaneous changes to their genes. Some gene mutations allow bacteria to produce enzymes that inactivate antibiotics. Others change their outer structure so that antibiotics can't gain access. Some bacteria even develop pumping mechanisms to expel antibiotics. Overuse and misuse of antibiotics has exacerbated the problem of antibiotic resistance. **BB**

What's the inside of a kangaroo's pouch like?

DAVID SIMPSON, BEDGEBURY

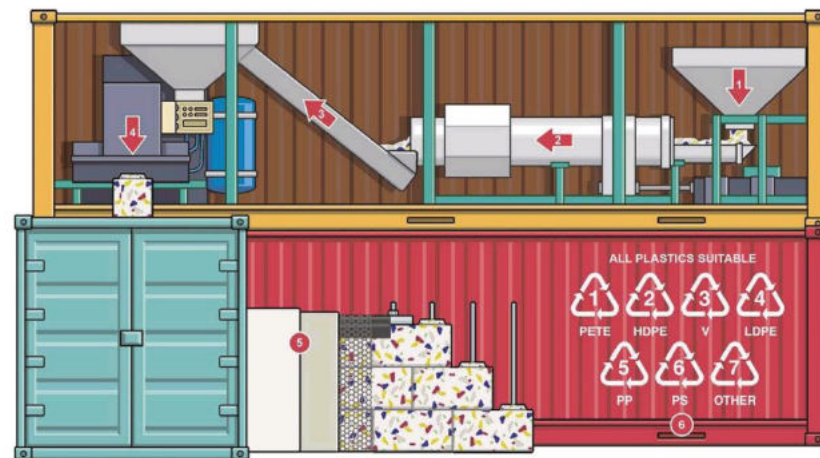
Newborn joeys, also known as 'jellybeans', quickly scale a wall of fur to climb into the warmth and safety of their mothers' cosy pouch. This fleshy pocket is stretchy and slightly sticky, and opens horizontally upwards to lessen the chance of the young falling out. The pouch is hairless inside and contains teats that produce milk of different types to feed joeys of different ages – a clever adaptation to enable offspring to be cared for at different stages of their development. Every now and then, mothers have to clean their babies' nursery to ensure it doesn't become smelly and unhygienic. They do this by licking inside the pouch to remove dirt, poo and urine – a true labour of love. **CC**

PHOTOS: GETTY IMAGES; SCIENCE PHOTO LIBRARY; ILLUSTRATIONS: BAJA LOCKEY

HOW IT WORKS

RECYCLED PLASTIC BUILDING BRICKS

Technology start-up ByFusion is currently developing machinery that can transform any waste plastic into building blocks



1. Plastic rubbish is put into the machine

2. The rubbish moves along into a shredder that cuts the plastic into smaller pieces.

3. The plastic is then mixed with superheated water and compressed

4. The bricks emerge from the machine and can be used for building

5. The bricks can be fixed together with metal rods to create structures, before being coated with chicken wire and mortar

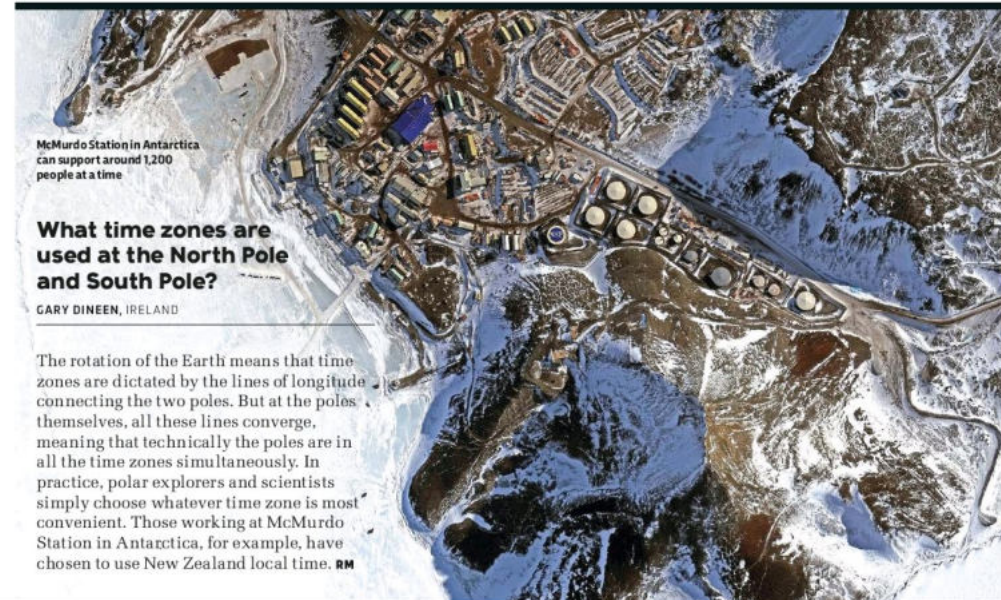
6. Any plastics can be used

McMurdo Station in Antarctica can support around 1,200 people at a time

What time zones are used at the North Pole and South Pole?

GARY DINEEN, IRELAND

The rotation of the Earth means that time zones are dictated by the lines of longitude connecting the two poles. But at the poles themselves, all these lines converge, meaning that technically the poles are in all the time zones simultaneously. In practice, polar explorers and scientists simply choose whatever time zone is most convenient. Those working at McMurdo Station in Antarctica, for example, have chosen to use New Zealand local time. **BM**



What is the current death/birth rate ratio in the world per year?

ANTHONY PERRY, USA



According to the World Bank, for every 1,000 people in the world, an average of 7,748 people will die each year and 19,349 will be born. That's a ratio of about 2.5 births for every death. Those figures are from 2014 but both are slowing at similar rates, so the ratio hasn't changed much in the last 10 years. **lv**

HEAD TO HEAD



MO FARAH

VS



USAIN BOLT

1.75m	HEIGHT	1.95m
60kg	WEIGHT	94kg
4	OLYMPIC GOLD MEDALS	8
12.98s	100m	9.58s
3min 56.49s	MILE	4min 30s (estimate)

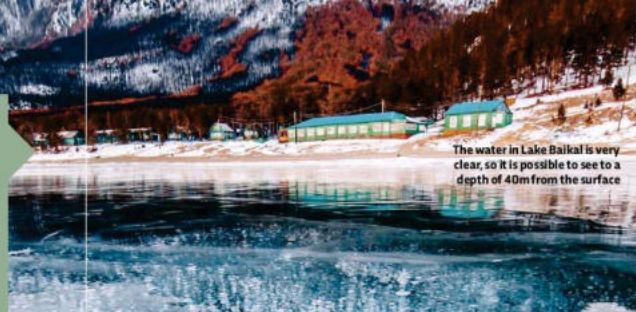
Usain Bolt is the fastest human in the world, but only up to 200m. His huge legs, packed with fast-twitch muscle fibres, allow explosive acceleration but they can't sustain prolonged

aerobic exertion, making them dead weights over longer distances. Usain Bolt has never actually run a mile, but most experts think he'd struggle to get a time under 4min 30s.

What is the deepest lake on Earth?

ELLIE PEARSON, NORTHAMPTON

This title goes to 1,642m-deep Lake Baikal, which is located in southern Siberia. The lake is part of an ancient rift valley, and has formed as the planet's crust slowly pulls apart in that area. It contains around one-fifth of the world's unfrozen freshwater reserves. Its isolation and age have led to the evolution of an unusual ecosystem, containing many plants and animals that are unique to the area. When winter rolls around, a thick layer of ice can form on the lake's surface, trapping streams of bubbles released from algae living in the chilly depths.



The water in Lake Baikal is very clear, so it is possible to see to a depth of 40m from the surface

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Why are human brains so big?

LIZZIE ALTON, GLASGOW

One possibility is that large brains are sexier. The person that can make music and art, or tell stories, may be more attractive to potential mates. But in the 1990s, anthropologist Robin Dunbar suggested that humans might also need large brains to keep track of their complicated social lives. Human social circles normally comprise around 150 people, compared with 50 for chimpanzees. Larger social groups have exponentially more interrelationships and our survival and success depends on being able to react to and predict the behaviour of our peers. Related to this is the idea of social dominance. Once our ancestors had begun to master their environment, their biggest threats were other humans. Leadership tussles within and between tribes favoured smarter humans much more than those that were just stronger. **lv**

Why can't we remember early life?

KAREN EVANS, LEEDS



Our inability to remember anything from before the age of three or four is referred to as infantile amnesia and it's still fairly mysterious. We do know that infants can form long-term memories: chat to a three-year-old about past events and you'll see for yourself. In fact, one study

showed that three-year-olds had a memory of an adult they'd met just once when they were aged one. But for some reason, likely related to the immaturity of infant memory processes, our earliest memories are lost by the time we are about seven years of age. **q**

WHO REALLY INVENTED?

THE TELESCOPE

HANS
LIPPERSHEYLEONARD
DIGGES*

In 1992, a telescope built by the British astronomer and historian Colin Ronan was shown on *The Sky At Night*. Telescopes have been vital to science since Dutch spectacle maker Hans Lippershey patented the now-familiar arrangement of lenses in 1608.

But what made Ronan's telescope different was that it was built to a design pre-dating Lippershey's by decades. Ronan claimed that an Elizabethan surveyor named Leonard Digges had found a combination of a glass lens and curved mirror that also made distant objects appear closer. Descriptions of the device began to circulate around 1570, and its potential military use prompted Lord Burghley, chief adviser to Elizabeth I, to commission a report. After discovering this manuscript in the British Library, Ronan built the device, and suggested that it had a claim to being the first telescope. He also suggested Digges's son, Thomas, had used it to observe the sky years before Galileo. Ronan's claim has failed to convince historians, however. They argue that Elizabethan technology was not capable of making the optical components to the required quality, and that the telescope is too awkward to use in any case. So the consensus remains that Lippershey is the originator of the first working telescope. **AM**

*No images of Leonard Digges are available



The Nicobar pigeon is an island specialist, and is mostly found in Southeast Asia and the western Pacific

What is the dodo's closest living relative?

PIPPA NEILSON, ST ALBANS

The dodo's closest relative was the Rodrigues solitaire, a large bird that lived on the island of Rodrigues in the Indian Ocean. But that's also extinct. Those two formed their own group, which was equally related to all pigeons. So there isn't a single living species the dodo was closest to. Their group

branched off from the pigeon family before the pigeon family radiated. Some records (bit.ly/nicobar_pigeon) list the Nicobar pigeon as the closest living relative of the dodo. This is based on genetic comparison, which is more reliable than inferring relationships from physical characteristics. **AP**

What's the neurological difference between anaesthesia and sleep?

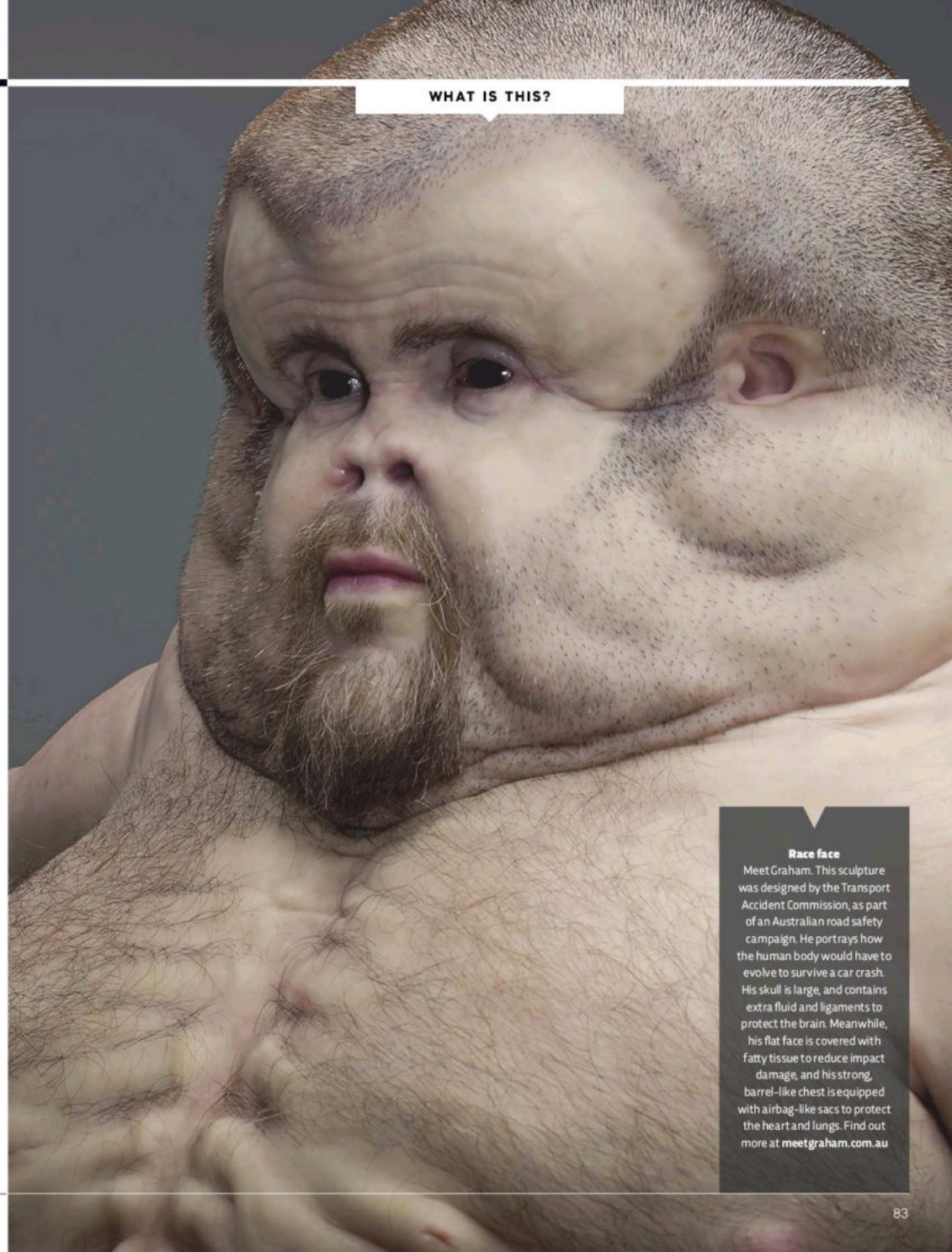
SOPHIA WAN, CROYDON

If a neuroscientist used electroencephalography (EEG) to record your brain's electrical activity while you were under anaesthesia, the results would look different from how they appear when you are sleeping. In fact, your brain waves under anaesthesia would more closely resemble those seen were you to have the terrible misfortune of falling into a coma after brain illness or injury. Doctors often tell surgery patients that they will be 'put to sleep' during the operation, but in terms of the neurological effects of the anaesthesia, it would be more accurate (and more unsettling) to tell them that they will be put into a reversible coma. **q**



PHOTOS: GETTY XL; TRANSPORT ACCIDENT COMMISSION

WHAT IS THIS?

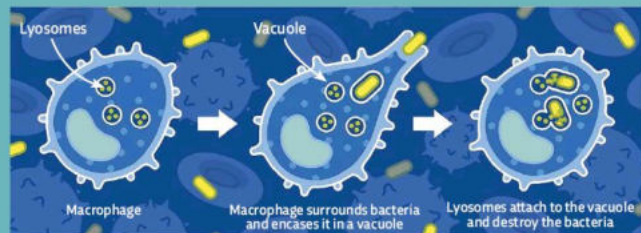


Race face

Meet Graham. This sculpture was designed by the Transport Accident Commission, as part of an Australian road safety campaign. He portrays how the human body would have to evolve to survive a car crash. His skull is large, and contains extra fluid and ligaments to protect the brain. Meanwhile, his flat face is covered with fatty tissue to reduce impact damage, and his strong, barrel-like chest is equipped with airbag-like sacs to protect the heart and lungs. Find out more at meetgraham.com.au

Why do you take longer to heal as you age?

TOM PATERSON, CARLISLE



Wound healing is a complex process involving the immune system. Unfortunately, some parts of the immune system deteriorate as we get older. For example, ageing affects the function of white blood cells (shown above) called macrophages (big eaters). These cells play key immune roles, especially in wound repair. They chomp their way through debris at a wound site, and help to promote tissue reconstruction by producing a growth factor that boosts the cells that make connective tissue and collagen. Meanwhile, in broken bones, macrophages secrete chemicals that attract stem cells to the injured site. Ageing also appears to alter these important interactions between macrophages and stem cells. **SB**

Are self-driving cars any good at parking?

PAT WARD, CHESTERFIELD

The new FF91 electric car by Faraday Future demonstrated how self-parking is not always perfect, by staying resolutely stationary during its big unveiling at CES 2017. Thankfully, automated parking is improving. The best cars of 2017 will tell you when a gap is big enough, will position themselves correctly and can do

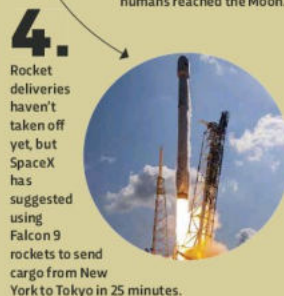
perfect parallel parking all by themselves: steering, gears, accelerator and brakes – you don't even need to be inside the car. However, if you want the most secure way of parking, try a robotic garage that moves your car like a parcel into its own slot, already in operation at the The Palais Coburg Hotel, Vienna, Austria. **PB**



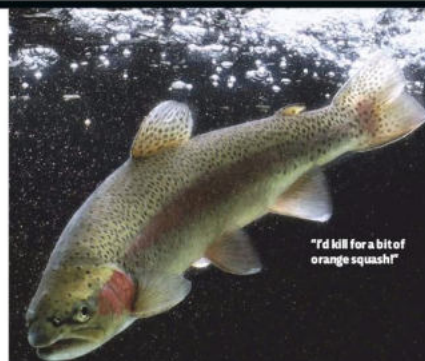
Self-parking cars eliminate any parallel parking woes

WHAT CONNECTS...

...FIRST CLASS POST AND FALCON 9?



PHOTOS: GETTY X2; ALAMY; WIKIMEDIA; SPACEX; ILLUSTRATIONS: BHAALCOCKEY



"I'd kill for a bit of orange squash!"

Do fish drink?

ANGELA COBB, LEICESTER

Depending on where they live, fish either drink a lot or pee a lot. In the sea, a fish's body is less salty than its surroundings, so it loses water across its skin and through its gills via osmosis. To stop themselves dehydrating, marine fish drink masses of seawater and produce a trickle of concentrated urine. When migrating fish like trout and salmon move into rivers and lakes, they face the opposite problem and risk absorbing too much water until eventually their cells begin to swell and burst. To avoid this, they switch from being heavy drinkers to plentiful urinators. **MS**

Why does the sea smell like the sea?

ALINE SMITH, LONDON

Saltwater by itself doesn't have any smell, but the things that live in it certainly do. The rather stale, sulphury smell is dimethyl sulphide, produced by bacteria as they digest dead phytoplankton. At low tide, you'll also smell chemicals called dictyopterenes, which are sex pheromones produced by seaweed eggs to attract the sperm. And on top of all this is the 'iodine' smell of the sea, which is actually the bromophenols produced by marine worms and algae. **LV**

Will e-learning replace teachers?

EDWARD SEYMOUR, HOVE

Online courses and interactive forums are becoming important in many countries as they allow students to gain access to a greater depth and breadth of information than a teacher may be able to provide. At Georgia Institute of Technology, Prof Ashok Goel went one step further. He runs an online course in knowledge-based artificial intelligence, and created an AI teaching assistant to respond to forum posts from his students. Goel only admitted to them it was an AI after four months, "blowing their minds". But studies also show that interaction with real people is still vital to enable children to develop normally. Children who use computers excessively show a measurable deficiency in social skills. **PB**



PHOTOS: NASA; GETTY X2

Is the flag still on the Moon?

HARRIET FYFE, FALKLAND ISLANDS



Six flags were planted on the Moon – one for each Apollo landing. Apollo 11's flag was too close to the rocket exhaust when Armstrong and Aldrin took off again. But high resolution images from the Lunar Reconnaissance Orbiter show that the other five are still standing. The flags were made of ordinary nylon though, so they have all long since been bleached white by the Sun. **LV**



Do any other animals get male pattern baldness?

CHRIS SAUNDERS, COLCHESTER

The sensitive response to androgen – a sex hormone – is an important feature of human hair. At puberty, hair grows in places where we had none; and as we age, changes in hormonal levels can lead to thinning hair in both men and women, and to baldness in some. But humans are not the only animals to experience this. It happens in chimps

and stump-tailed macaques in nearly the same way. And mice, rats, hamsters, rabbits and sheep became sensitive to fur loss when their androgen levels were manipulated in the laboratory. There was even a report in which wattled starlings in the wild displayed a bald scalp in response to natural changes in androgen levels. **AP**

QUESTION OF THE MONTH

Why do the centres of galaxies contain black holes?

ADAM KING, HUDDERSFIELD

Since the 1960s, astronomers have uncovered evidence that most galaxies contain so-called supermassive black holes at their cores. With masses between a million and a billion times that of the Sun, these leviathans first revealed their presence in so-called quasars – distant galaxies with cores so luminous the only plausible source of power is the intense gravity of black holes devouring matter. Since then, studies of stellar orbits have shown that even relatively tranquil galaxies like our own Milky Way harbour hefty black holes. Their origin remains a mystery, however. They may have been created by the gravitational collapse of giant gas clouds from which galaxies were formed, or from the merger of many smaller black holes over time. Another possibility is that one simply grew over billions of years by steadily devouring orbiting stars. **RM**

WINNER!

Adam King wins two Blink security cameras. These monitors are temperature- and motion-sensitive, and let you check on your home instantly via the Blink app (£109.99 each, blinkforhome.co.uk).



NEXT ISSUE:

Why aren't all plastics recyclable?

Why does skin wrinkle with age?

Will time ever end?

PHOTOS: NASA, GETTY X2

Email your questions to questions@sciencefocus.com or submit online at sciencefocus.com/qanda

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RICHARD ROBINSON,
BRIGHTON SCIENCE FESTIVAL



HAPPY BIRTHDAY ALL YEAR!

What could be more fun than a gift that keeps coming though the letterbox every month? If you wish the first issue can be dispatched in time for the special day, along with your gift message.



March Issue: Mr Hawking's BIG idea

This month **AQUILA** investigates the life and space-times of the UK's science superstar. Children can go **black hole** hunting; investigate the concept of **space and time**, and stretch their brains to the **outer limits**! PLUS: Lucy Hawking tells us what it is like to have a genius for a dad.

See sample issue and more info about **AQUILA** at:
www.AQUILA.co.uk Tel: 01323 431313

OUT THERE

WHAT WE CAN'T WAIT TO DO THIS MONTH

APRIL 2017

EDITED BY JAMES LLOYD



PHOTO: GETTY



01

STARGAZING LIVE
LIVE ON BBC TWO, 28-30 MARCH

EXPLORE THE SOUTHERN SKY

Stargazing Live returns this March, but with a twist – Prof Brian Cox and Dara O Briain will be broadcasting live from Australia. For three nights they'll be camped out deep in the Outback, beneath some of the darkest skies in the world.

It's the perfect time of year for stargazing Down Under, with the bulging heart of the Milky Way directly overhead and the planet Saturn swinging into view with its famous rings. In the southern sky, familiar objects such as the Moon and the Orion constellation appear upside down, while we'll see famous stars and constellations such as the Southern Cross, Scorpius and Alpha Centauri that are rarely, if ever, visible from the UK.

Meanwhile, we'll hear haunting tales of Aboriginal astronomy, meet some of the wildlife that stalks stargazers in the Outback, and find out why Australia is in the firing line for contact from aliens. Maybe they just like warm beer...

DON'T MISS

STARGAZING LIVE

Are you a beginner to astronomy? Pick up this special edition from the team behind *Sky At Night* Magazine. On sale now.



02 EXPERIMENT WITH OUR FOOD

Want to cook up a delicious meal? It's not just about the food. We chat to psychologist PROF CHARLES SPENCE about the strange science of gastrophysics

What exactly is gastrophysics?

It's a combination of 'gastronomy' and 'psychophysics', which involves the scientific study of how our experience of food and drink is affected by our senses and our surroundings, not just the food itself. It's a small but growing area of research which brings together psychologists, neuroscientists, marketers, chefs, product designers and even musicians.

So what kinds of things can affect our sense of taste?

Pretty much everything! From the colour and shape of the plates to the weight and material of the cutlery, through to the shape of the table and the feel of the chair you're sitting on. Then there's the number of people you're with, the mood you're in, the lighting and background music in the restaurant, and memories associated with the food. When you put all these factors together, it adds up to a lot.

Just how important are these effects?

It's hard to say exactly how much [of the taste] is down to the food and how much is the 'everything else', but Paul Bocuse, one of France's foremost chefs, has said that more than half of the experience of what he serves is the 'everything else'. Obviously some things matter more than others – the background music is going to have more of an impact than the shade of paint on the restaurant walls, for instance.

What's the most surprising way in which our taste can be influenced?

It's the idea of 'sonic seasoning', which uses sounds to change the taste of food. You can add as much as 15 per cent extra sweetness, sourness, or bitterness to a food simply by playing the right sort of music. We've created music to enhance sweetness (high-pitched and tinkling) and bitterness (low-pitched and brassy), and we also have music for sour, umami and spicy foods. Working with the Michelin-starred chocolatier Dominique Persoone in Belgium, we even showed that if we played 'creamy' music (slow and legato) in his stores we could add extra creaminess to his chocolate.

Neuroscientists have found direct connections in the mouse brain between the senses of smell and sound, so it might be that this occurs in humans too. Sonic seasoning is already being used to enhance meals in fancy restaurants and culinary events, but we could also see it being used to benefit health by, for example, playing 'sweet' music so that we're happy with less sugar in our food.

How is our sense of taste influenced by the colour of the plate?

There are probably two or three things happening here. It might be to do with the contrast between the colour of the plate and the colour of the food – our brain will find it harder to pick out porridge (and process its taste) when served in a white bowl, for instance. A number



This duck and beetroot dish was created by Charles Spence's Kitchen Theory. If viewed upside-down, Picasso's face can be seen in the meal

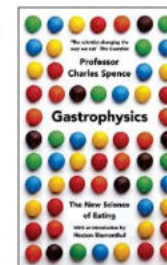
PHOTOS: WWW.KITCHEN-THEORY.COM

"Studies show that serving food off red plates can suppress appetite"

of studies also show that serving food off red plates can suppress appetite, possibly because this is the colour of danger and 'stop'. And there's also the effect of our expectations. If we're used to eating ice cream from a round, white bowl, then our brain will already expect something sweet when we're served food in a similar dish.

What's the most innovative use of gastrophysics you've seen?

There's a lot happening in the world of cutlery design. Heston Blumenthal's restaurant The Fat Duck is currently serving a dish called Counting Sheep, which comes with a fluffy, weighted spoon that smells of baby powder, designed to enhance the eating experience. We've found that food tends to taste better with heavier cutlery – possibly because we associate weight with quality.



GASTROPHYSICS
BY PROF CHARLES SPENCE
OUT 30 MARCH (£14.99, VIKING).



+ PROF SPENCE'S FIVE TIPS TO TRY AT HOME



THINK ABOUT THE MUSIC

To bring out the authenticity of a dish, try playing ethnically appropriate background music (such as sitar music while eating a curry). If you want to bring out the sweetness of a dessert, go for some tinkling piano music.



TURN OFF THE TV

Turning off the TV makes us more mindful about what we're eating. People have been shown to eat up to 30 per cent more when the TV is on.



EXPERIMENT WITH PLATEWARE

Don't just go for a round, white plate. Try serving something on a slate, a plank of wood, or even out of a plant pot. Or simply change the plate colour. These will all affect your food's taste.



MAKE AN IMPRESSION

We're only eating for a few moments, so a lot of the pleasure is in the memory of a meal. Create surprise by combining unexpected flavours and textures (remember Heston's bacon and egg ice cream?).



DITCH CUTLERY

More and more restaurants are getting rid of cutlery. We didn't evolve to eat with cold stainless steel, and eating with our hands adds another sense to the experience. Just don't try it with risotto.



03

ME AND MY DOG: THE ULTIMATE CONTEST
BBC TWO IN APRIL. CHECK RADIO TIMES.

CELEBRATE OUR DOGS

The bond between man and dog goes back thousands of years, so it was perhaps only a matter of time before we had a TV show dedicated to this enduring relationship. *Me And My Dog* will see eight people and their dogs competing in a series of physical and mental challenges, designed to find out who has the closest relationship with their canine companion.

Presented by Chris Packham over four weeks, the contest takes place amidst the rugged terrain of the Lake District, with disciplines including paddle-boarding, canine parkour, and a tethered cross country run. Along the way, we'll learn about the science of dog training, and find out just what makes the human-pooch bond so strong.

04

EDINBURGH INTERNATIONAL SCIENCE FESTIVAL
1-16 APRIL
SCIENCEFESTIVAL.CO.UK

GO NORTH

Scotland's capital city is set to become a hive of science-themed activity this April, with the return of the Edinburgh International Science Festival. The theme of this year's festival is 'get connected', and there are more than 250 events lined up for children and adults.

The City Art Centre will be transformed into a science playground, offering families the chance to create their own coral creatures, build humanity's first Mars colony, and design their own slime. Meanwhile there are other happenings across the city, from science theatre and brand new exhibitions to a hands-on Experimentarium and a gig from sample-tastic space-pop pioneers Public Service Broadcasting. Check out the full programme at sciencefestival.co.uk/whats-on.



DON'T FORGET

TURN OFF THE LIGHTS

People all over the world will be switching off their lights for an hour to show support for action on climate change. To find out what's happening in your area, visit the website.
EARTH HOUR, 25 MARCH, 8.30PM-9.30PM
EARTHHOUR.ORG

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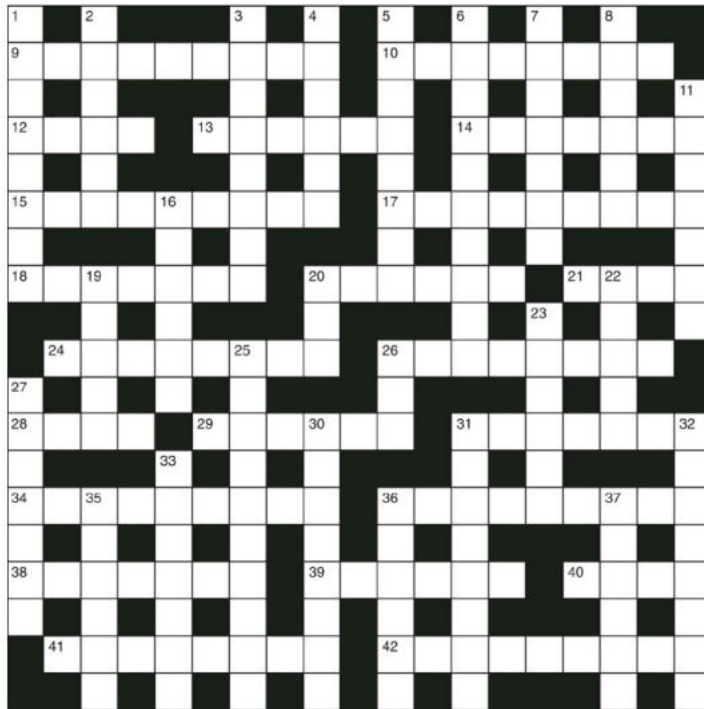
kew.org/safeguardinglife

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SCIENCE CROSSWORD

GIVE YOUR BRAIN A WORKOUT



ACROSS

- 9 Soldier to gauge an auxiliary variable (9)
 10 Student rings European about hard legal ambiguity (8)
 12 Level of wage increase, say (4)
 13 So nice to have reassessed function (6)
 14 Two follow ceremony east to doomed city (7)
 15 Room to turn and mislay plant structure (9)
 17 Awfully greyscoop about self-levelling device (9)
 18 Try open form of confusion (7)
 20 Sunset captured by fellow German (6)
 21 Old friend gets a stone (4)
 24 Greek hero has a cold and takes additives (8)

- 26 Technophobes did let us work (8)
 28 Curse that may be Hippocratic (4)
 29 Maroon beach (6)
 31 Sue ran behind shopping centre for part of hearing (7)
 34 Daughter organised help in America for dolphin (9)
 36 Developed poor, clear material (9)
 38 Hum bits composed about metal (7)
 39 Skin contains a large binary compound (6)
 40 Spots synonym for reckless (4)
 41 Quickly take erroneous core prediction (8)
 42 Open tidal movement in celestial object (9)

DOWN

- 1 Replicas constructed of respiratory aperture (8)
 2 Country nut (6)
 3 Go to lie about unknown study of causation (8)
 4 Just like a bear, ruins excursion east (6)
 5 Everyone turns green – that produces a reaction (8)
 6 Policeman finds chief a crawler (10)
 7 I'm returning trunk outside shop (7)
 8 Consort lost right to perform in reflected light (6)
 11 Dismiss insect as a beetle (7)
 16 Ideal spot to view Thomas More's vision (6)
 19 Understood to be in Latin (5)
 20 British and American group of conductors (3)
 22 Bit of quiet is heard (5)
 23 Venetian island and river have one voice (6)
 25 Hate talent displayed by quality of changing matter (6, 4)
 26 Guided by a small light (3)
 27 Spanish city has attachment to old graduate (7)
 30 Art-lover sculpted the seat with energy (8)
 31 I'd remain puzzled by line of longitude (8)
 32 Plus arrangement to conceal compound (8)
 33 Church has a cure devised for poet (7)
 35 Left racket to return injury (6)
 36 Ruler of state gets terribly hip (6)
 37 Hardly overdue bringing back optical instrument (6)

ANSWERS

For the answers, visit bit.ly/BBCFocusCW
 Please be aware the website address is case-sensitive.

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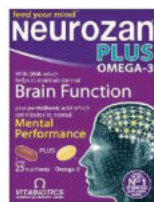


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NEXT MONTH



MAY
ISSUE ON SALE
18 APRIL

PHYSICS

The truth about time

It's a topic that has the greatest minds scratching their heads. What exactly is time? Where does it come from? And in what direction does it flow? Follow us down the rabbit hole...

AI

ROBOTS THAT LEARN

Robots are getting smarter by the week, but just how close are they to the next big leap in their evolution – the ability to learn from humans and think for themselves?



PHOTOS: GETTY

WILDLIFE

SAVE THE PANDA?

The giant panda has recently been downgraded from endangered to vulnerable. So is it time to transfer money and resources to conserving other threatened species?



TECHNOLOGY

DRIVERLESS CARS PRIMER

Whether you like it or not, we'll soon be sharing our roads with autonomous vehicles. In fact, your next car could be driverless. Before you buckle up, read our guide to this game-changing technology.



"I worked with one serial killer, a trained butcher, who dismembered people"

Forensic psychologist **Kerry Daynes** talks to **Helen Pilcher** about psychopaths, stalkers and the surreal side of working with serial killers

What do you do?

I've spent a lot of my career working with people who have severe personality disorders, including psychopaths and sexual offenders. It was my job to make them less of a risk.

What's it like working with these people?

It can be surreal. I worked with one serial killer, a trained butcher, who dismembered people. You have to build up a rapport with people in order to work meaningfully with them, so we cooked together. He taught me how to bone a turkey! All along I was aware these were the same skills that he used on his victims.

Which are you more like, Clarice Starling or Cracker?

Neither, these fictional characters are 'profilers'. Cracker was an emotionally damaged Scot who tramped all over crime scenes. It's an inaccurate portrayal of what people like me do. But anything that sparks the public's interest in science and psychology is okay in my book.

What was it like the first time you met one of these offenders?

It was a baptism of fire. I was 21 years old, doing research in a high-security prison, interviewing men who had raped and murdered their victims. While it was daunting, I was able to separate myself from it emotionally and get on with the job. In the end, the prison officers were more difficult than the offenders.

How do you mean?

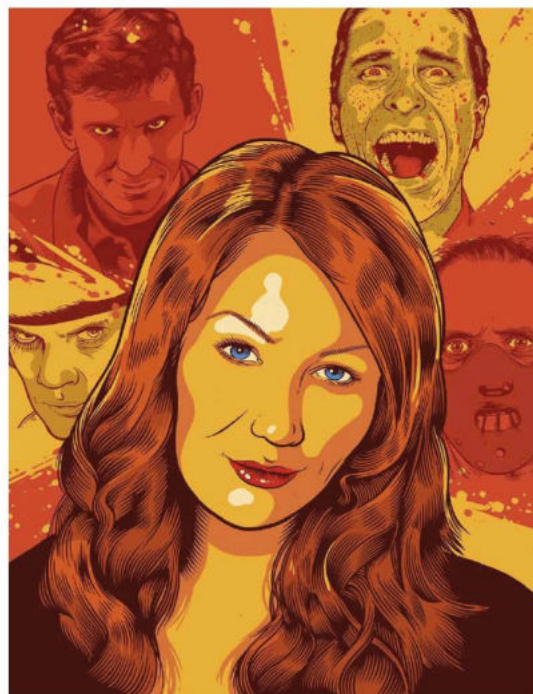
It was an incestuous, institutional male environment. The guards ordered me to remove my shoes because they were 'too sexy'. They even ran a book on who would be the first to sleep with me! Things have moved on since then and I don't work in prisons any more. Forensic psychology is actually a very female world.

Does your professional life ever spill into your private life?

I became the victim of a stalker. He watched me, bought websites in my name and said damaging things about me in public. The police could only issue a harassment warning but I took civil action against him. It stunned me how inadequate the current laws are, but it did give me first-hand knowledge of what it's like to be a victim.

Do you ever think about quitting?

I've worked with the most misogynistic, dangerous men imaginable. It takes its toll. I made a conscious decision a while ago to stop working with them and start working more in general mental health and with victims. I've also branched into the corporate sector.



Do you meet many psychopaths in the business world?

Yes! One in every 100 people are psychopaths and 20 per cent of CEOs score highly on psychopathic traits. Moderate levels of psychopathic-like traits can be useful, as long they're tempered with compassion and humility. I draw on my unique experiences to teach skills to business leaders.

I think I am going to worry about you. Promise me you'll be okay?

I'm pretty resilient. I come from a very stable and 'normal' background; that helps. I also have two enormous dogs, Humphrey and Fozzchops. When the complexity and inhumanity of some humans feels a little overwhelming, the simplicity and innocence of a happy dog is a great antidote. ☺

Kerry Daynes is a consultant psychologist who has worked with some of the most notorious criminals in the UK. Her most recent book is *Is There A Psycho In Your Life?*

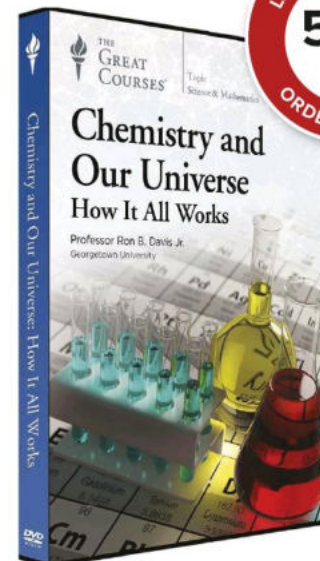
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